Wanipigow River Water Quality Data, August 2002

Status Report

By D. J. Green

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Water Branch

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1.0 Background

The Wanipigow River System is located on the east side of Lake Winnipeg more than 100 km north of the mouth of the Red River in the Lake Winnipeg South Basin. The headwaters of the Wanipigow River are located in Ontario near the Manitoba/Ontario border. The Wanipigow River flows through Siderock, Wallace, and Wanipigow lakes before emptying into the northern portion of the Lake Winnipeg South Basin across from Black Island (Figure 1).

Water quality samples were collected from various locations along the Wanipigow River system during August 2002 (Figure 2). Sampling was conducted following discussions with Councillor Brian Moneyas of the Hollow Water First Nation in early summer 2002. The Hollow Water First Nation had concerns about water quality in the Wanipigow River and had requested collection of some water quality data.

Historical water quality data had been collected from Wanipigow Lake during the mid-1970s, early 1980s, and in 1992. However, there was no record of historical water quality data for the Wanipigow River on the Water Quality Management Section database of Manitoba Conservation. The most recent water quality data from the Wanipigow River were collected during the fall of 2000 and spring 2001 by the gold mining operation in Bissett (Harmony Gold). These data were collected in conjunction with discharge from their final tailings polishing pond. As part of the conditions for the two discharges from the tailings polishing pond, the mining company was required to monitor water quality on the Wanipigow River upstream and downstream of the discharge route confluence to the river. Subsequent discharges from the tailings management area of the operation have not been necessary to-date because the company temporarily suspended operations. Upstream and downstream sampling sites on the Wanipigow River during the discharge periods were approximately 20 and 12 km upstream (linear distance) of Wanipigow Lake, respectively. Both these sites were also sampled during this investigation.

2.0 2002 Water Quality Sampling

2.1 Sampling Locations

Water quality sampling locations along the Wanipigow River were selected based upon historical water quality sampling sites, sites previously used to monitor potential effects from periodic discharge of treated wastewater effluent from the gold mining operation in Bissett Manitoba, and new locations that provided both upstream and downstream data from potential sources of impact. Accessibility was also an important factor in choosing sampling sites. Figure 2 shows a general overview of water

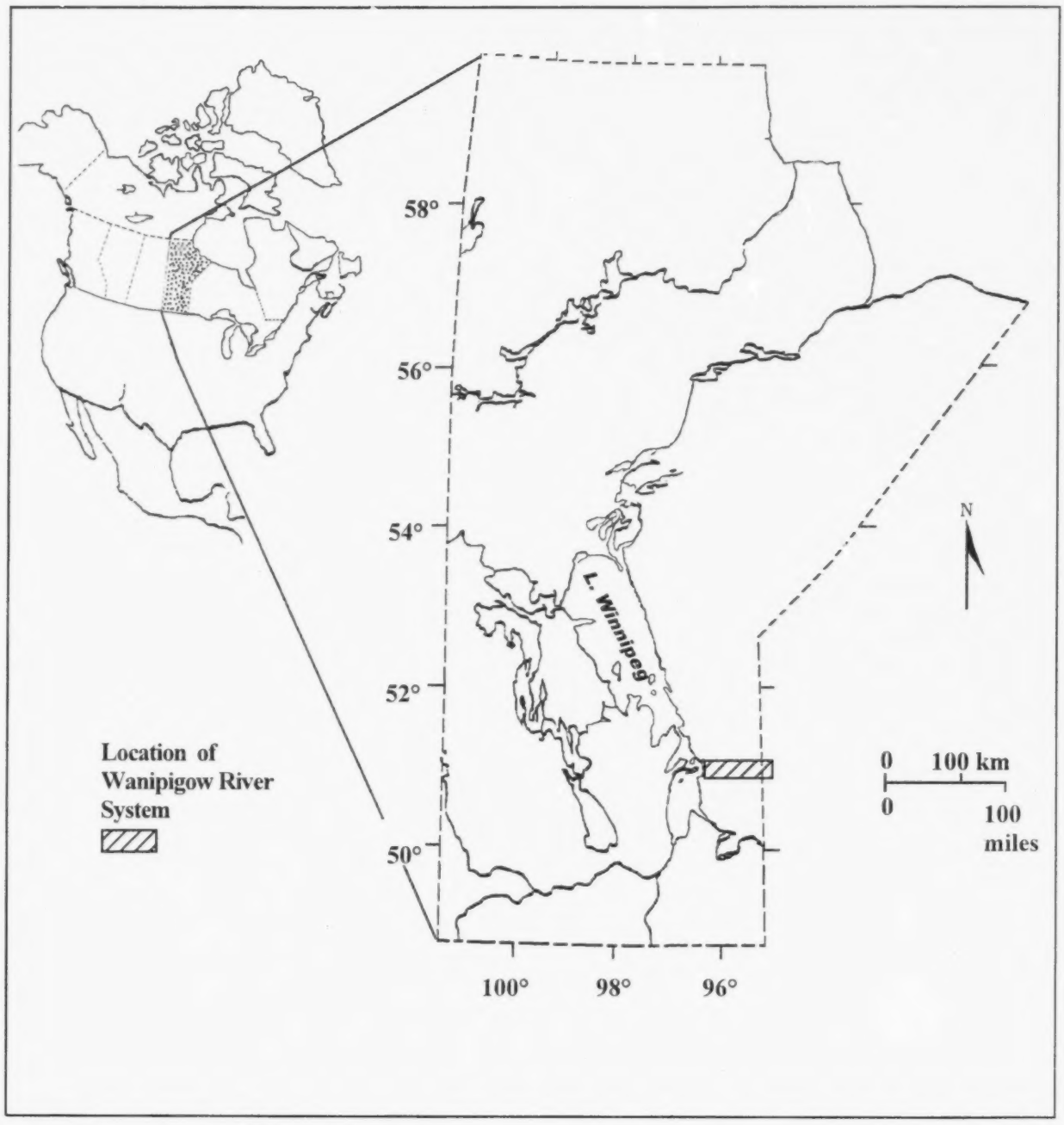

Figure 1. Geographic location of the Wanipigow River system in Manitoba, Canada.

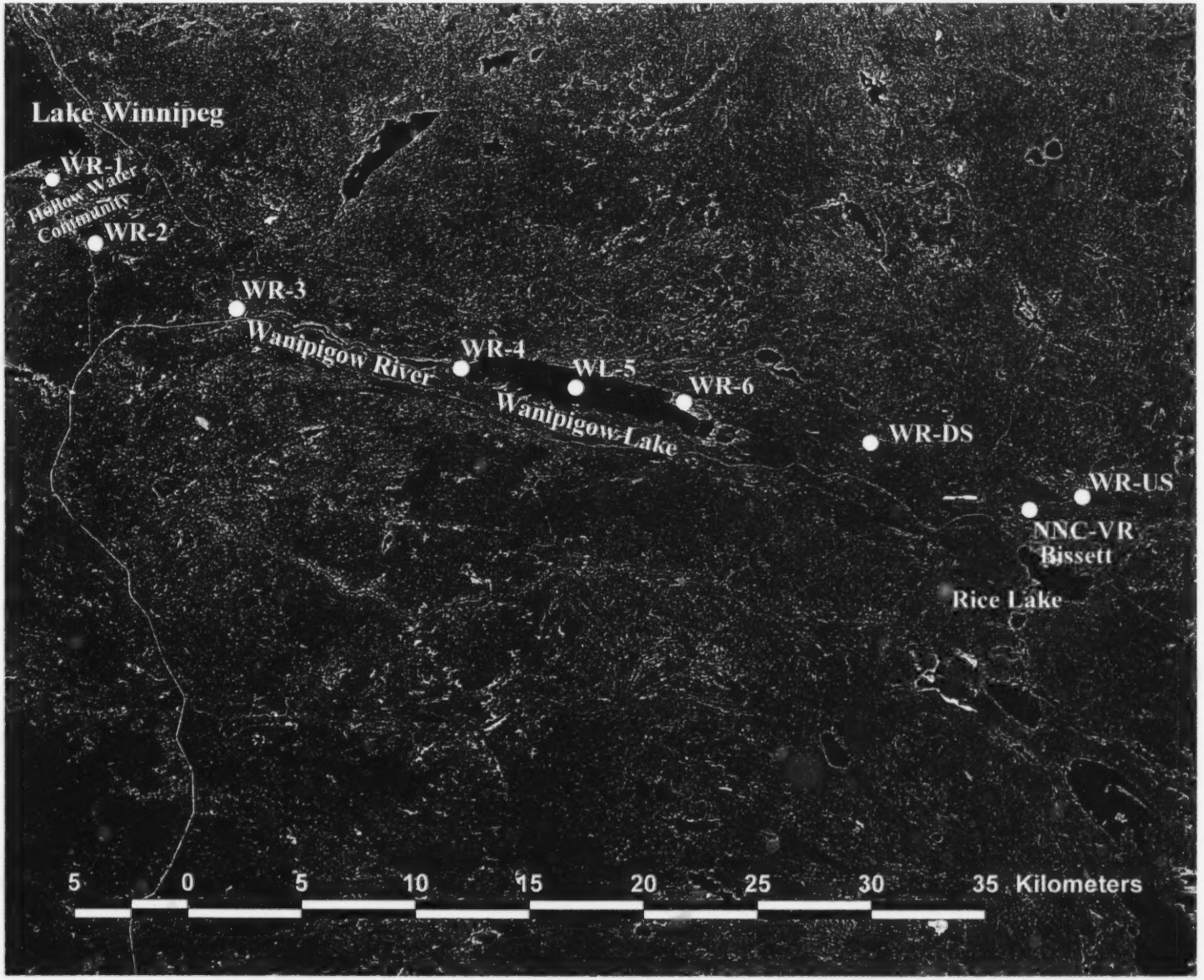

Figure 2. Water quality sampling sites for the Wanipigow River System , August 2002.

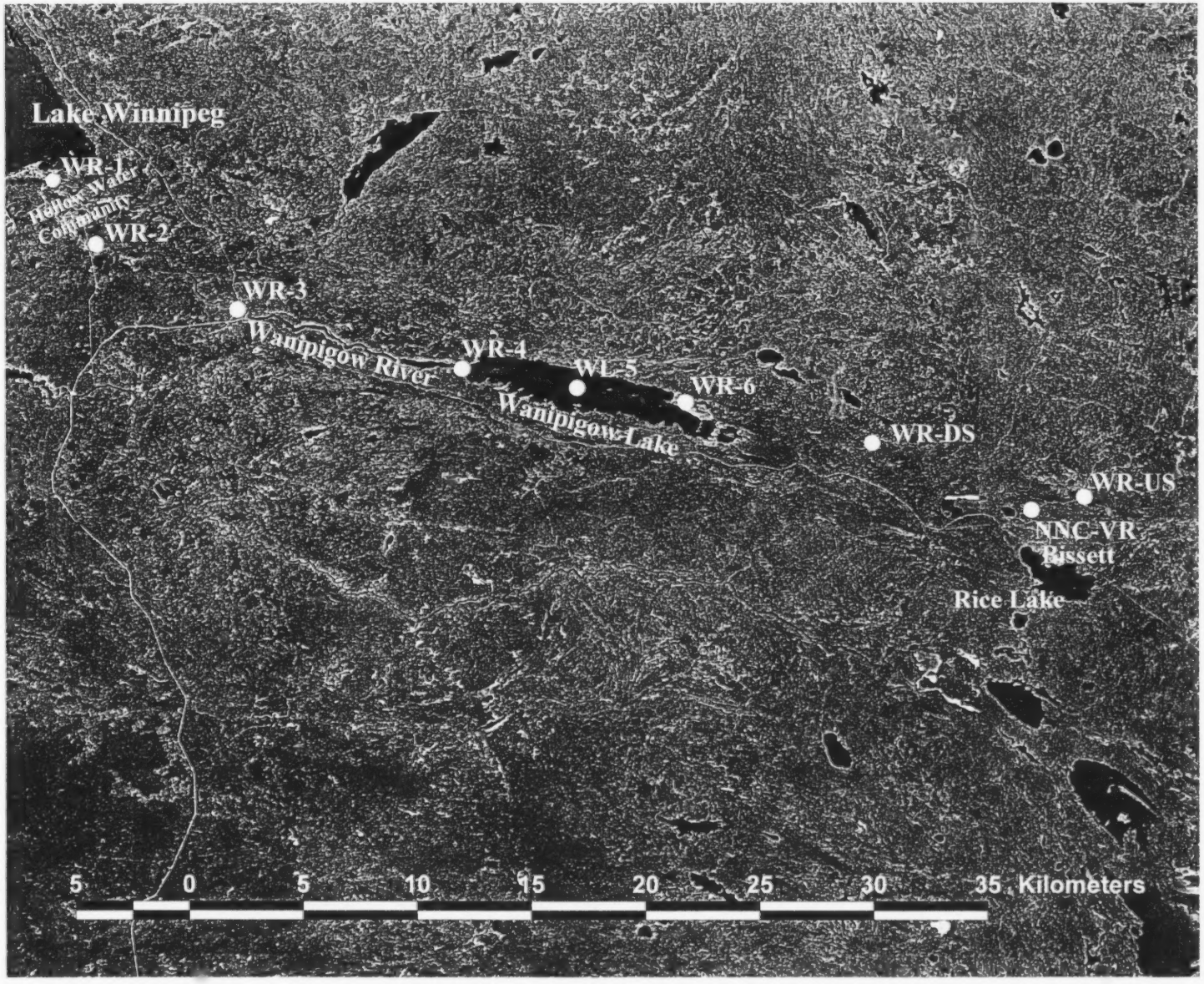

Figure 2. Water quality sampling sites for the Wanipigow River System , August 2002.

quality sampling sites along the Wanipigow River. More detailed aerial photos of individual sites are provided in Appendices 1 and 2.

The most upstream sampling site (WR-US) on the Wanipigow River occurred upstream of the discharge route confluence (No-Name Creek) from the mining operation located in Bissett MB. A water sample was also collected at one of the sites (NNR-VR) on No-Name Creek that was monitored when the mine discharged treated tailings water in the fall of 2000 and spring 2001. Table 1 (Page 5) provides a list and description of sampling sites in order from the most upstream to downstream site.

2.2 Water Collection Methods

Water samples from most river sites were collected from near the water surface with a sampling device that was either lowered from a bridge crossing or attached to a telescoping, hand-held pole extended from shore. Water samples from the river inlet, river outlet, and mid-basin of Wanipigow Lake were collected by boat. Samples from the river inlet and outlet sites were collected from the water surface by submersing the sample bottles to approximate elbow depth. The mid-basin water sample from Wanipigow Lake was collected by a trace metal grade Kemmerer to a depth of approximately 1 m. Water samples were kept dark and cool in a cooler immediately after collection. Water chemistry and bacteriological samples were transferred within 36 hours of collection to CanTest Laboratories[1] and Enviro-Test Laboratories[2], respectively.

2.3 Units of measurement and Symbols

Common units of measurement or symbols used throughout this report are as follows:

mg/L (milligrams per litre)	Equivalent to parts per million (ppm)	or approximately equivalent to one thimbleful (1.5 mL) in four to five average sized bathtubs of water
µg/L (micrograms per litre)	Equivalent to parts per billion (ppb)	or approximately equivalent to one thimbleful in two Olympic sized swimming pools
km (kilometres)	Equivalent to 0.6 miles	
m (metres)	Equivalent to 39.37 inches or one yard Imperial measurement	
<	Less than	

[1] CANTEST Laboratories, 675 Berry Street, Winnipeg MB R3H 1A7.
[2] Enviro-Test Laboratories, 745 Logan Avenue, Winnipeg MB R3E 3L5.

Table 1. Site identification and descriptions for water quality sampling sites on the Wanipigow River System, 2002. Sites are arranged in an upstream to downstream order.

Sampling Site Id (Generic) [Database site identification]	***Site Orientation***	***Site Characteristic***	***Site Description***
Wanipigow River (WR-US) [MB05RAS119]	Most upstream sampling site	Road bridge crossing	Shallow (< 0.5 m) with rock bottom, riffle current, extensive deciduous vegetation on both banks
No-Name Creek (NNR-VR) [MB05RAS122]	On the discharge route from the final tailings pond prior to entering the Wanipigow River	Road culvert crossing on Vanson Road	Small shallow creek with mud bottom, very little current, extensive vegetation & wetland areas along banks
Wanipigow River (WR-DS) [MB05RAS120]	Currie's Landing Road	Road bridge crossing	Shallow (< 0.5 m) with exposed rock, riffle current, extensive deciduous vegetation on both banks
Wanipigow River (WR-6) [MB05RAS146]	Main river channel entering Wanipigow Lake (north channel)	Boat accessible only	Approximately 4.3 m deep, slow moving current, floating bog, emergent, and deciduous vegetation along shores
Wanipigow Lake (WR- 5) [MB05RAS003]	Mid basin of Wanipigow Lake	Boat accessible only	Approximately 5 m deep
Wanipigow River (WR-4) [MB05RAS145]	Outlet channel from lake	Boat accessible only	Approximately 2.5 m deep with mud bottom, extensive emergent and deciduous vegetation along shores
Wanipigow River (WR-3) [MB05RAS144]	Bridge crossing on Ravens Creek Road	Road bridge crossing	Shallow (< 0.5 m) with rock bottom, exposed rock, riffle current, extensive vegetation on both banks
Wanipigow River (WR-2) [MB05RAS143]	At upstream edge of Hollow Water community development & downstream of Ramsay Rapids	Shore access from dock	Slower moving current, extensive emergent vegetation on shores
Wanipigow River (WR-1) [MB05RAS142]	Most downstream site near mouth of Wanipigow River	Road bridge crossing	Slow moving current, cleared areas along shore

3.0 Results and Discussion

3.1 General

Water in a natural state contains numerous different naturally occurring elements and compounds. In some instances, concentrations of elements or compounds under naturally occurring conditions may exceed guidelines for the protection of aquatic life or for other uses of water. However, human activities will often have a greater and further influence on the characteristics of the water. The nature, degree, and scope of human activities near a water body generally determine the extent of any impacts. To assist in the understanding of water quality, Appendix 3 provides a synopsis of the significance of many different elements and compounds that are usually measured in water.

Water quality data collected during 2002 are provided in Appendices 4 to 6. Historical data for the sampling location at the mid-basin of Wanipigow Lake (WL-5) were included in these appendices since this was the only historical site monitored during 2002. The remainder of the historical data and a figure showing locations of historical sampling sites on Wanipigow Lake are included in Appendices 7 and 8, respectively.

3.2 Fecal Coliform and Escherichia coli (E. coli) Bacteria

Fecal coliform bacteria are micro-organisms found in the intestinal tracts of all warm blooded animals (*i.e.*, humans, mammals, and birds). Natural sources such as contributions from wildlife (*e.g.*, beaver or birds) can cause fecal coliform numbers in the hundreds to a few thousand CFU (colony forming units) per 100 mL of water.

Fecal coliform bacteria values include a variety of species such as *E. coli* and *Klebsiella spp.* bacteria. *Eschericia coli* have been monitored more regularly in conjunction with fecal coliform bacteria in recent years since they are considered more representative of human sources such as municipal discharges or leaching from septic systems. Although *E. coli* can originate from wildlife, elevated values (especially around human sources) can indicate potential problems with sewage effluent discharges or faulty septic systems.

Fecal coliform and *E. coli* bacteria samples on the Wanipigow River system ranged between < 10 CFU/100 mL (laboratory detection limit) to 100 CFU/100 mL (Appendix 4). The highest number of both fecal coliform and *E. coli* bacteria occurred at the most upstream sampling site (WR-US). Most of the elevated values occurred at sites upstream of Wanipigow Lake (Appendix 4). However, the fecal coliform bacteria values from these sites were considered to have probably originated from wildlife because of their locations. The sampling sites were relatively remote and distant from any human activity compared to the opportunity for the presence of wildlife. There was evidence of beaver and waterfowl activity at many locations along much of the river system that would provide a greater opportunity for contribution than human sources.

Most fecal coliform and *E. coli* values from Wanipigow Lake and sites downstream of the lake were 10 CFU/100 mL or less. Although one fecal coliform value at site WR-3 was 60 CFU/100 mL, the fecal coliform bacteria probably originated from

wildlife or waterfowl in the area. The *E. coli* value at this site was only 10 CFU/100 mL (Appendix 4). These relatively low values indicated fecal bacteria values were well within the range often encountered with contributions from natural sources. This indicated that there was not a significant contamination problem from septic systems or other human sources at this time.

3.3 Secchi Disk and Chlorophyll-a Measurements

Secchi disk measurements give an indication of light transparency through the water column. The greater the secchi disk reading, the better the visibility through depth in the water. Greater secchi disk numbers correspond to less turbidity or material suspended in the water column. Chlorophyll-*a* values represent the amount of green plant pigment present in water (primary production), and therefore, provide a surrogate indication of algae abundance in the water column. Higher chlorophyll-*a* values indicate a greater abundance of algae. Consequently, secchi disk measurements and chlorophyll-*a* measurements often show an inverse relationship to each other.

Secchi disk measurements were not collected at most river sites because proper measurements could not be taken from bridge locations and the water depth was often shallow with a relatively swift current (Appendix 9, photos 1, 3, and 7). Secchi disk measurements were taken at the inlet (WR-6), mid-basin (WL-5), and outlet (WR-4) of Wanipigow Lake. Secchi measurements at these sites were fairly low and ranged between 0.61 m to 0.80 m (Appendix 4). The secchi disk measurement from the mid-basin of Wanipigow Lake during 2002 was slightly lower than historical mean values during the early 1980s (0.77 m to 0.80 m, Hughes 1982, 1983) and about 38 % lower than in 1992 (Appendix 4). During 1992, the mean secchi disk reading in the mid-basin was about 0.99 m. It was considered that the measurement from August 2002 might have been lower than historical readings due to windy conditions during sampling. There was a fairly strong wind and wave action prior to and during data collection and this may have stirred up suspended matter in the lake reducing visibility. Wanipigow Lake is relatively shallow with the majority of depth ranging between 2.5 m to 5.0 m (Anonymous 1984). There was no indication that the reduced visibility was due to an algal bloom or increased values of chlorophyll-*a*. There was no visible indication of an extensive algal bloom during sampling, although the windy conditions may have mixed the algae throughout the water column and masked a noticeable bloom. However, the 2002 chlorophyll-*a* value was usually lower than historical values from 1992.

Chlorophyll-*a* values were relatively low from all sites during 2002 and ranged between 1.7 µg/L to 12.2 µg/L (Figure 3, Appendix 4). The lowest chlorophyll-*a* values occurred at the upstream river sites, while the highest value was near the confluence of the Wanipigow River with Lake Winnipeg. Values at most sites were less than 5 µg/L, which is generally considered low. It is not known why the value at the mouth of the river increased to 12 µg/L, but it could have been due to slightly higher nutrient values in this lower reach and more favourable conditions for algal growth. Slightly higher nutrient values in the lower reach probably resulted from accumulated upstream effects, although periodic discharge of treated wastewater from the community lagoon could have also significantly contributed to nutrient values in the immediate area. Similar to a lake

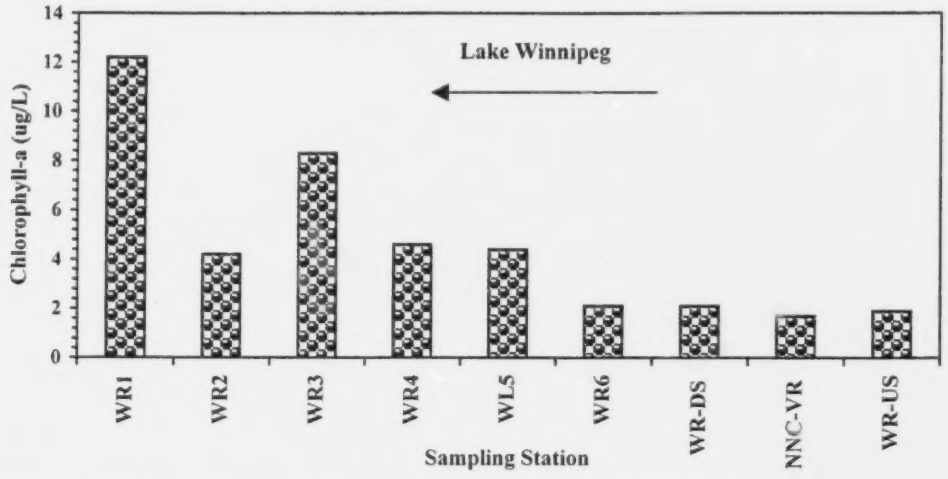

Figure 3. Total chlorophyll-*a* concentrations from the Wanipigow River system, August 2002.

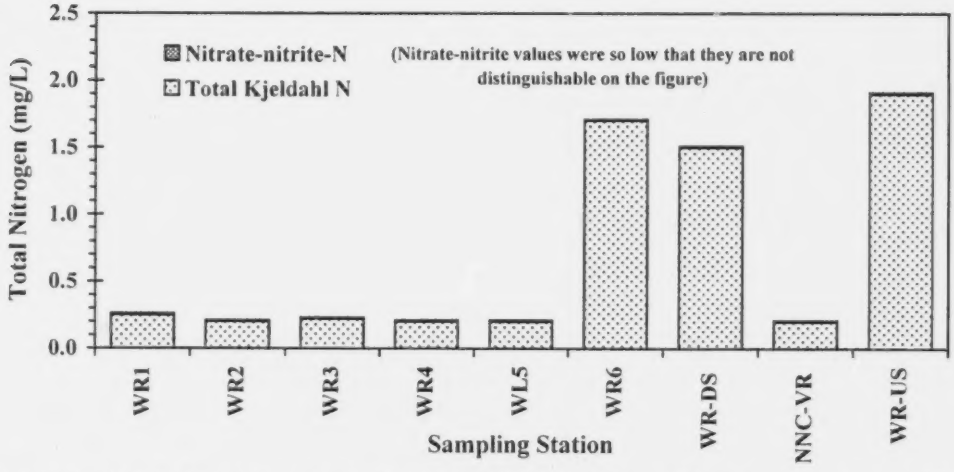

Figure 4. Total nitrogen concentrations from the Wanipigow River system, August 2002.

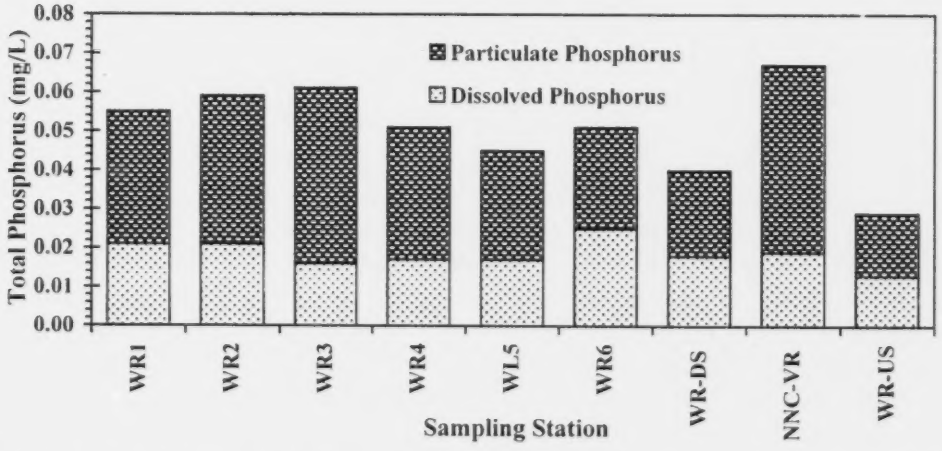

Figure 5. Total phosphorus concentrations from the Wanipigow River system, August 2002.

situation, energy (flow) in the lower reach of the river near the confluence with Lake Winnipeg (Appendix 9, photo 8) appeared lower than many upstream sites (Appendix 9, photos 1, 3, and 7), and this combined with slightly higher nutrients may have allowed algae to better establish. Also, this site is near Lake Winnipeg and there may be some occasional backwater effect or onshore wind action that allows nutrients and algae from the lake to be pushed into the river mouth.

The relatively low secchi disk readings from Wanipigow Lake were not attributed to nuisance algal blooms, but to the high colouration in the water. Water-colour throughout the system ranged between 50 to 100 colour units and these values are generally considered fairly high (Appendix 4). The colour of the water in the Wanipigow River system is fairly brown (Appendix 9, photo 6), and is caused by natural tannic and organic acids derived from decaying vegetation. Although the Wanipigow River system is on the Canadian Shield, there are extensive areas of bog throughout the watershed that can provide coloured water as the vegetation decays. Lakes on the Canadian Shield that have low inputs from bog and wetland areas generally have low colour values (< 10 colour units).

3.4 Nutrients

Nutrients are necessary for all living organisms to survive. In aquatic systems, too many nutrients usually does not negatively affect aquatic plant growth, but an overabundance of nutrients can cause excessive or nuisance algal or other weed growths. These excessive occurrences of algae or aquatic weeds may be aesthetically unpleasant, hamper boat navigation and other recreational activities, or may have more detrimental impacts to other aquatic life such as fish and molluscs. Under some circumstances, large algal blooms may cause oxygen concentrations in water to reach critically low values for fish as the bloom dies-off and the decaying process consumes oxygen in water faster than it can be replenished. Some species of cyanobacteria (blue-green algae) can produce toxins that are toxic to animals drinking untreated surface water. It is not well understood at this time how cyanobacteria blooms that periodically produce these toxins may impact upon fish or other aquatic life.

3.4.1 Nitrogen Species

Nitrogen is an important nutrient for plants to survive. Nitrogen species include inorganic forms such as ammonia nitrogen and nitrate-nitrite nitrogen as well as nitrogen bound in organic material. Organically bound nitrogen along with ammonia nitrogen comprises total Kjeldahl nitrogen (TKN). Total Kjeldahl nitrogen provides a general indication for potential future available inorganic nitrogen since it includes organically bound nitrogen that becomes available during decaying processes. Total Kjeldahl nitrogen minus ammonia nitrogen provides an estimate of the total organic portion. Nitrogen in an organic form such as in vegetation matter must be converted to an inorganic form (ammonia nitrogen or nitrate-nitrite nitrogen) before other plant matter

can utilize it. Total nitrogen (TN) is determined by adding TKN and nitrate-nitrite nitrogen concentrations.

Total nitrogen values from most sites on the Wanipigow River system were relatively low with values < 0.5 mg/L (Figure 4, Appendix 4). The highest nitrogen values ranged between 1.5 mg/L to 1.9 mg/L (Figure 4), and occurred at sites upstream of Wanipigow Lake (WR-US, WR-DS, and WR-6, Figure 2). Almost all of the total nitrogen for all locations was in the form of TKN (organically bound and ammonia nitrogen). Nitrate-nitrite nitrogen values were less than the laboratory detection limit (0.01 mg/L), while ammonia nitrogen values were slightly elevated. There was not any indication of a trend between upstream and downstream locations since the ammonia nitrogen value at the most upstream sampling site (WR-US) was similar to values at the most downstream sites (WR-1 – WR-3, Figure 4). Ammonia nitrogen and TKN values from Wanipigow Lake mid-basin (WR-5) and outlet (WR-4) were usually lower than other locations indicating localized contributions at downstream sites were providing an additional source of nitrogen.

As previously discussed, there are some fairly extensive areas of wetlands/bog along this river system. It would appear that relatively active organic breakdown of plant matter occurred near all sampling locations, although organic nitrogen values downstream of Wanipigow Lake were less than 1 % of TN. Meanwhile, organic nitrogen values upstream of Wanipigow Lake were in the range of 70 % to 90 % of TN (Appendix 4).

3.4.2 Phosphorus

Phosphorus (P) includes a particulate and dissolved form. Particulate phosphorus (PP) includes the portion contained in organic matter or attached to silt particles and is not readily available to aquatic plants. Dissolved phosphorus (DP) is generally comprised of inorganic orthophosphates and is more readily available to plants. Phosphorus is often the nutrient in the most limited supply, *i.e.*, occurring at lower concentrations than nitrogen and thus limiting the amount of aquatic plant growth. There is often enough nitrogen available and as more phosphorus is added to a system, aquatic plants can respond accordingly. Canadian Shield lakes usually have lower P values than prairie lakes because the thin soils overlaying the Canadian Shield bedrock have lower amounts of nutrients for leaching than the more nutrient rich soils in agri-Manitoba. There is also generally less man-induced influence in shield areas.

Phosphorus concentrations in the Wanipigow River generally appeared relatively high for being on the Canadian Shield and ranged between 0.029 mg/L at the most upstream site (WR-US) to 0.061 mg/L at the upstream edge of development in the Hollow Water community area (WR-3) (Figure 5, Appendix 4). There was a general increase in P concentration with downstream progression, although an increase in concentration between each consecutive downstream site was not consistent. For example, P concentrations entering and exiting Wanipigow Lake at WR-6 and WR-4 were both 0.051 mg/L. Meanwhile, the P concentration in the lake mid-basin was lower (0.044 mg/L, Figure 5). This indicated that inputs entering Wanipigow Lake were diluting and probably settling out somewhat to bottom sediments. This condition is

expected since lakes frequently act as settling basins from river discharge as the energy of the river is dissipated into the wide open basin. It is not fully known why P concentrations increased from the mid-basin of Wanipigow Lake to the outlet site, but may be due to wind action and the shallow nature of the lake at the outlet site (WR-4). Depth at WR-4 was only 2.5 m. Particulate P was higher at WR-4 than WR-6, and given the windy conditions experienced on the lake during the day of sampling, some fine bottom-sediment bound P may have been re-suspended in the water column. The DP concentration from WR-4 and WL-5 (lake mid-basin) were both 0.017 mg/L (Figure 5), further indicating increases at WR-4 were probably caused by PP from disturbed lake bottom matter.

The P concentrations in the Wanipigow River system would appear to be mainly due to the fairly extensive bog and wetland areas in the watershed since other development between sampling locations is relatively limited. Because of the extensive amount of vegetation in bogs and wetlands, P concentrations can be higher in these water bodies due to the extensive vegetation matter available for decay and release of P to other receiving waters. Inputs of P can also occur from sewage lagoon discharges or leaching from septic system fields, but these situations would mainly occur from cottages on Wanipigow Lake and in the community of Hollow Water.

The highest P concentration occurred at NNC-VR (No-Name Creek) and was 0.067 mg/L (Figure 5). The majority of P was in PP form and appeared it might have originated from the extensive vegetation/wetland source around this area. Flow and volume in this creek was very low (Appendix 9, photo 2) which would help concentrate P. Although the Town of Bissett has a sewage treatment lagoon, the discharge route does not enter No-Name Creek and the Wanipigow River watershed, but is directed towards Bog Creek and into Rice Lake (J. R. Cousins 1996).

The only historical data for P occurred from Wanipigow Lake (Appendices 4 and 7). The 2002 TP concentration (0.044 mg/L) from WL-5 (mid-basin) was higher than mean TP values from this site during 1976 (0.03 mg/L), 1977 (0.041 mg/L), and 1992 (0.038 mg/L), but lower than the mean value in 1980 (0.061 mg/L). It should be noted that data was usually very limited for each year and mean values were often only represented by two samples collected from different depths at a site on the same day (Appendix 4).

The most extensive single season data set for Wanipigow Lake occurred during 1992. Ralley and Beck (1995) observed P values on Wanipigow Lake during 1992 were variable between locations and over the course of summer, but there was not a statistical difference in the data from different areas of the lake or in trends throughout summer. They did not find evidence that human activities were significant sources of nutrients to Wanipigow Lake and determined it was mesotrophic (moderately enriched) based upon a Trophic State Index (TSI) developed by Carlson (1977). The 2002 data also indicated a similar status. It would appear that most of the TP values along the river system were mainly from natural sources (wetland/bog drainage, overland runoff, and atmospheric deposition) given the relatively limited known human sources compared to the size of the watershed.

3.5 General Chemistry

The pH of water indicates how acidic or alkaline the water is. A value of 7.0 units is considered neutral, while values above and below 7.0 units are considered alkaline and acidic, respectively. The pH of water in the Wanipigow River and Wanipigow Lake during 2002 was slightly alkaline and ranged from 7.05 units at WR-1 (most downstream site near confluence with Lake Winnipeg) to 7.38 units at WR-3 (upstream edge of Hollow Water community development (Figure 6, Appendix 4)). The lowest pH value (7.03 units) during 2002 occurred in No-Name Creek (NNC-VR) and was also slightly alkaline. Although bog and wetland drainage can often have pH values that are slightly acid (*i.e.*, between 6.5 to 7.0 units), alkalinity or buffering conditions in the watershed appeared to be compensating for any acidic drainage that occurred.

Alkalinity in water indicates the ability to buffer or neutralize acid inputs and bicarbonate alkalinity (HCO_3) in the Wanipigow system was moderate with a range of 32 mg/L to 61 mg/L (Figure 6). Alkalinity in No-Name Creek (NNC-VR) was substantially higher (264 mg/L). Similarly, conductivity (467 µS/cm) and water hardness (219 mg/L) were significantly higher in No-Name Creek compared to the main river system. Conductivity and water hardness in the Wanipigow River ranged between 64 µS/cm to 105 µS/cm and 33 mg/L to 58 mg/L ($CaCO_3$), respectively (Figure 6). Conductivity values were fairly typical of lakes on the Canadian Shield in Manitoba and relatively low compared to prairie water bodies. Hardness values were considered moderate for surface water in Manitoba.

Conductivity provides an indication of the electrical conductivity in water and is influenced by the amount of dissolved salts and minerals. Water hardness is mainly influenced by the calcium and magnesium content of water; higher values of these two variables will increase hardness. Both conductivity and water hardness showed slightly increasing trends from the most upstream to the most downstream sampling site on the Wanipigow River during 2002 (Figure 6, Appendix 4). However, there was no indication that values may have changed over time since values from Wanipigow Lake observed during 2002 were usually within the range of values from historical data collected during the 1970s and 1980s (Appendices 4 and 7).

3.6 Metals

A fairly wide suite of metals and minerals were analysed in 2002. Many metals not historically determined were done in 2002 due to increased capabilities in recent years with effective and economical laboratory analytical methods such as ICP-MS technology. Many of these water samples had metal values less than laboratory detection limits and included elements such as antimony, beryllium, bismuth, cesium, cobalt, molybdenum, selenium, silver, tellurium, thallium, thorium, tin, uranium, and zirconium (Appendices 5 and 6).

Analyses of trace metals historically measured in Manitoba waters such as cadmium and lead also had values less than laboratory detection limits. Other trace metals frequently monitored in Manitoba waters (*e.g.*, copper, nickel, and zinc), as well as the metalloid arsenic, indicated variability of concentrations between the Wanipigow

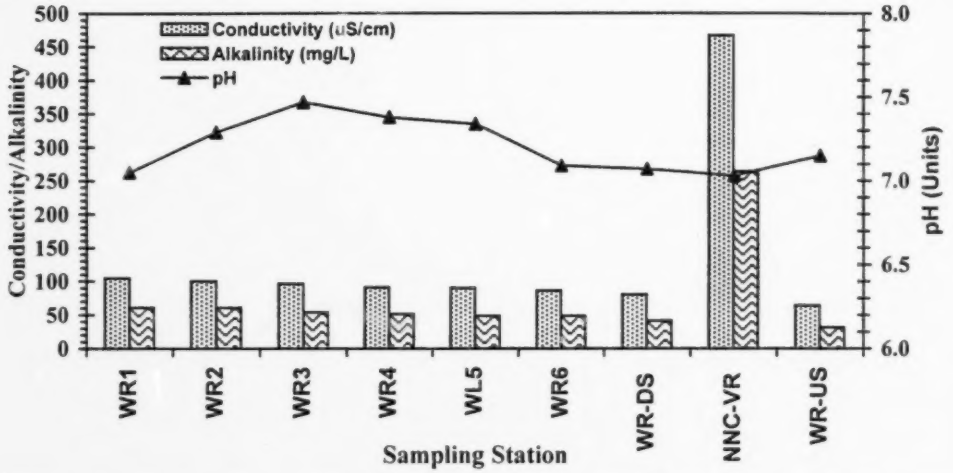

Figure 6. Conductivity, alkalinity, and pH concentrations from the Wanipigow River system, August 2002.

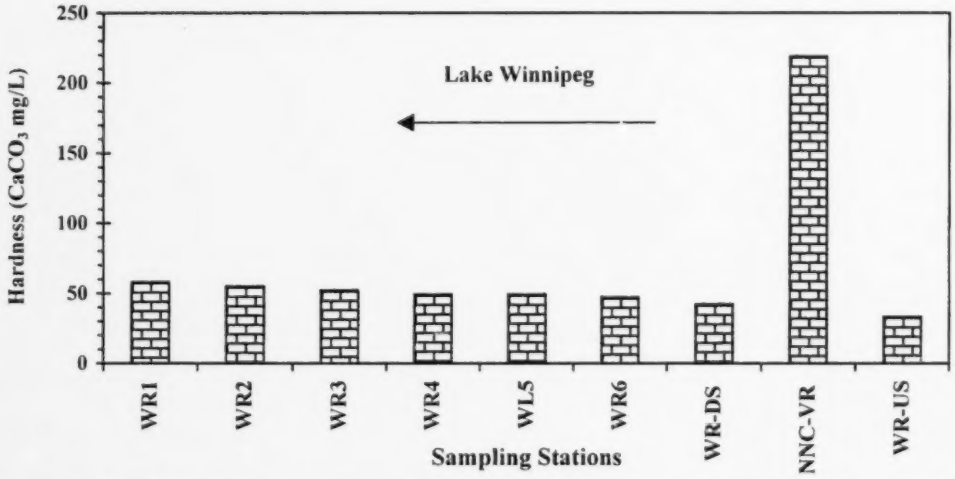

Figure 7. Water hardness concentrations from the Wanipigow River system, August 2002.

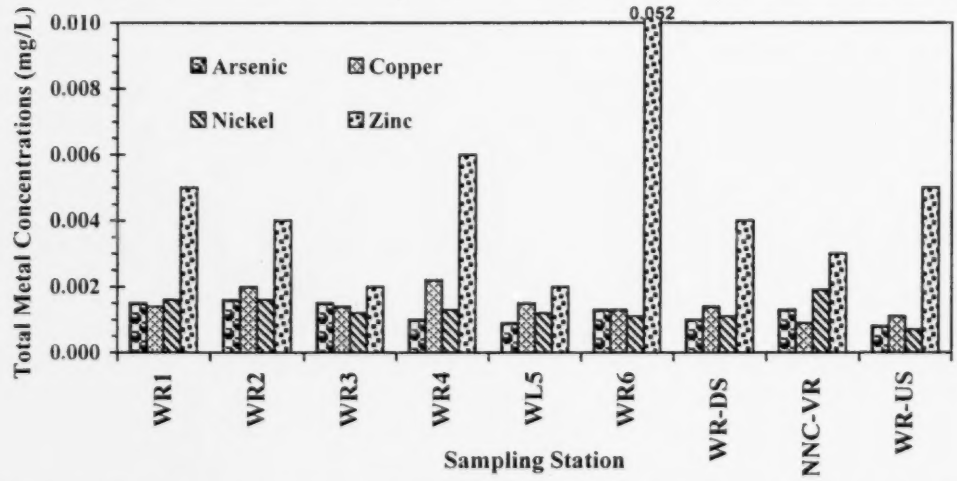

Figure 8. Total arsenic, copper, nickel, and zinc concentrations from the Wanipigow River system, August 2002.

River sites. There was no clear indication of a trend between upstream and downstream locations in 2002 (Figure 8). The only apparent consistency was lower values at the most upstream location (WR-US; upstream of Bissett and the mine operation) than other downstream sites, except for zinc (Appendix 5, Figure 8). None of the concentrations exceeded objective values for the protection of aquatic life (Williamson 2002, Appendix 3).

The concentration of total zinc (0.005 mg/L) was the same at the most upstream (WR-US) and downstream (WR-1; near mouth of Wanipigow River in Hollow Water) sites with the highest values occurring at Wanipigow Lake inlet (WR-6) and outlet (WR-4) sites (Figure 8). The value at WR-6 (0.052 mg/L) was more than an order of magnitude higher (10x) compared to the other sites (0.002 mg/L to 0.005 mg/L). It is not known why the zinc value at WR-6 was this high in 2002. It appeared to have been an anomaly possibly due to a sampling or analytical error because there was no indication that contributions from upstream areas would have caused this elevated value. Zinc concentrations from sites upstream of WR-6 were considerably lower in 2002. As well, total zinc values at WR-US and WR-DS (downstream of Bissett and mine discharge route) during monitoring of discharge from the mine tailings in the fall of 2000 and spring 2001 were an order of magnitude lower than the concentration at WR-6 in 2002 (unpublished data). None of the zinc concentrations in 2002 exceeded objective values for the protection of aquatic life (Williamson 2002).

The lowest concentration of total aluminum (0.12 mg/L) on the Wanipigow River was at the most upstream location (WR-US), while the maximum value (0.36 mg/L) occurred in Wanipigow Lake mid-basin (Appendix 5). These concentrations were higher than the guideline value for protection of aquatic life (0.10 mg/L, Williamson 2002). However, this condition can be a fairly common occurrence in many areas of the province, especially in areas where soils have fairly high clay content. Aluminum is a relatively abundant metal on earth comprising more than 7 % of the earth's crust. It appeared that aluminum in the Wanipigow River was mainly contributed from natural sources throughout the river system. No-Name Creek did not appear to be a major source since values at the NNC-VR site (0.031 mg/L) were almost an order of magnitude lower than river locations (Appendix 5).

Similar to aluminum, iron concentrations from all sites were above the guideline value for protection of aquatic life and aesthetic considerations for drinking water (0.3 mg/L). The aesthetic guideline for drinking water was established to reduce the potential for staining of laundry and plumbing fixtures. Iron, as with aluminum, is a relatively abundant metal on earth and it is not uncommon for naturally occurring concentrations in water to exceed guideline values. In 2002, iron concentrations ranged from 0.53 mg/L to 0.95 mg/L at WR-US (most upstream site) and WR-6 (Wanipigow Lake inlet), respectively (Appendix 5). Values in the lower part of the Wanipigow River downstream of Wanipigow Lake tended to be lower and ranged between 0.58 mg/L to 0.69 mg/L.

Manganese was the only remaining metal with concentrations that exceeded an aesthetic guideline (0.05 mg/L) for a drinking water. Similar to iron, this guideline was established to reduce the potential for staining plumbing fixtures or causing undesirable taste in drinking water. Manganese is often closely associated with iron so elevated values could be expected with elevated iron values.

4.0 Conclusions

The water quality in the Wanipigow River system is considered mesotrophic (moderately enriched with nutrients). Natural sources appeared to be the main origin of nutrients because known areas of development in the watershed appeared limited compared to the watershed size and water quality between sampling sites with no development was not always better than sites near a development.

There was no indication of significant changes to water quality in Wanipigow Lake since data from 2002 were usually within the range of values observed from historical data.

Specific observations were as follows:

- Fecal coliform bacteria and *E. coli* bacteria occurrences were generally low and considered to originate from natural sources such as wildlife or waterfowl.

- Light transparency (secchi disk values) in Wanipigow Lake were relatively low, but within ranges of historical data. These low secchi disk measurements were not attributed to an extensive algal bloom or other suspended matter, but to the high colour of the water due to natural conditions.

- Chlorophyll-*a* values were relatively low along the river system. Although still considered fairly low, the highest value occurred near the confluence of Lake Winnipeg and may be due to more favourable conditions for algal growth in this area than other parts of the river or from effects of Lake Winnipeg.

- Nitrogen concentrations were greatest at the upstream sites and were mainly in an organically bound form. Ammonia nitrogen concentrations were variable between sites, but were the same at the most upstream and downstream sites.

- Phosphorus concentrations gradually increased from upstream to downstream sites. Most of the increases were due to particulate phosphorus values and thought to be mainly contributed from natural sources. Phosphorus concentrations for 2002 data from Wanipigow Lake were within the range of values observed from historical data.

- Most metal concentrations were less than laboratory detection limits. Concentrations of aluminum and iron usually exceeded guideline values for protection of aquatic life. Observations from data between sampling locations on the Wanipigow River system suggested that concentrations were mainly due to natural conditions.

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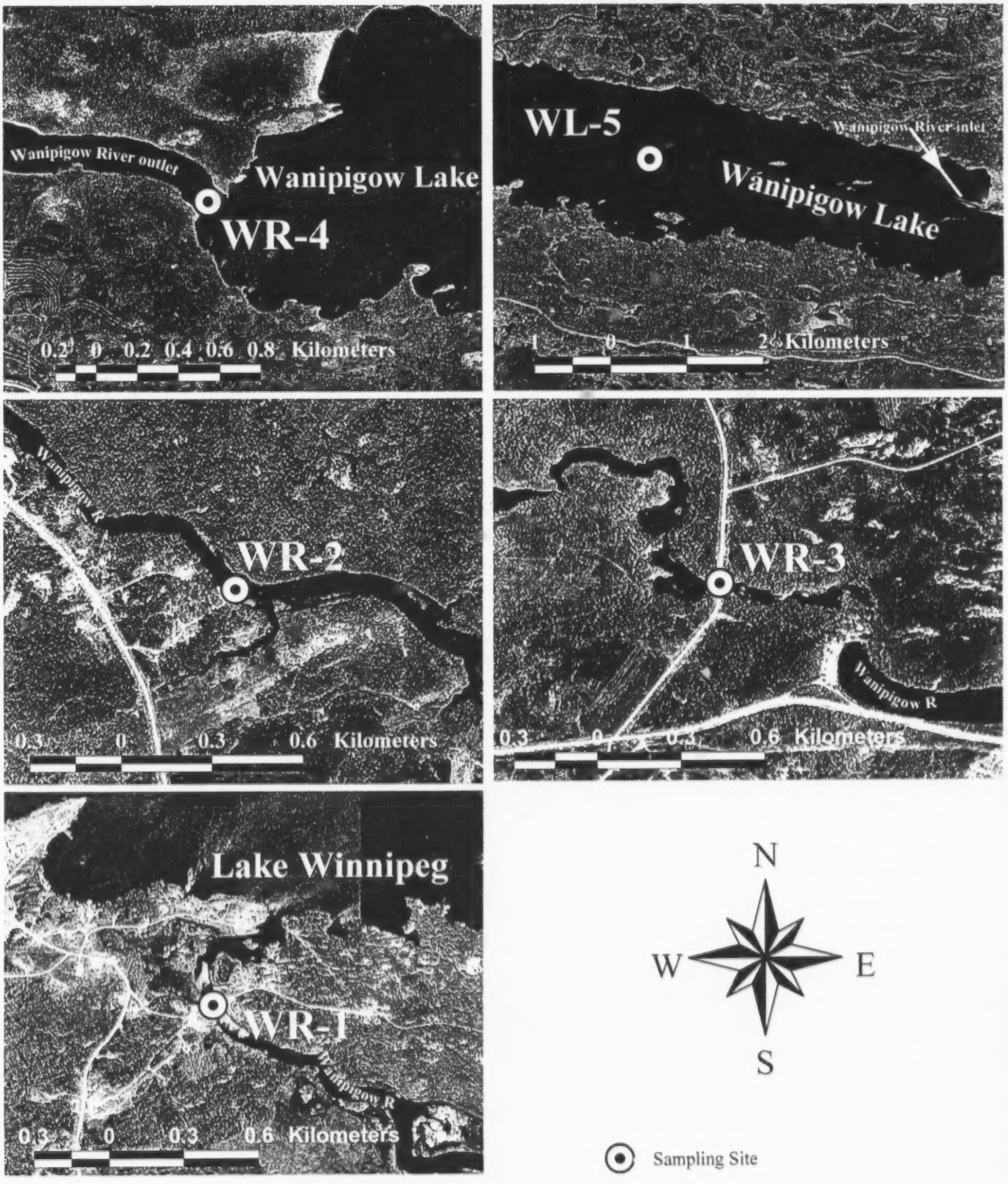
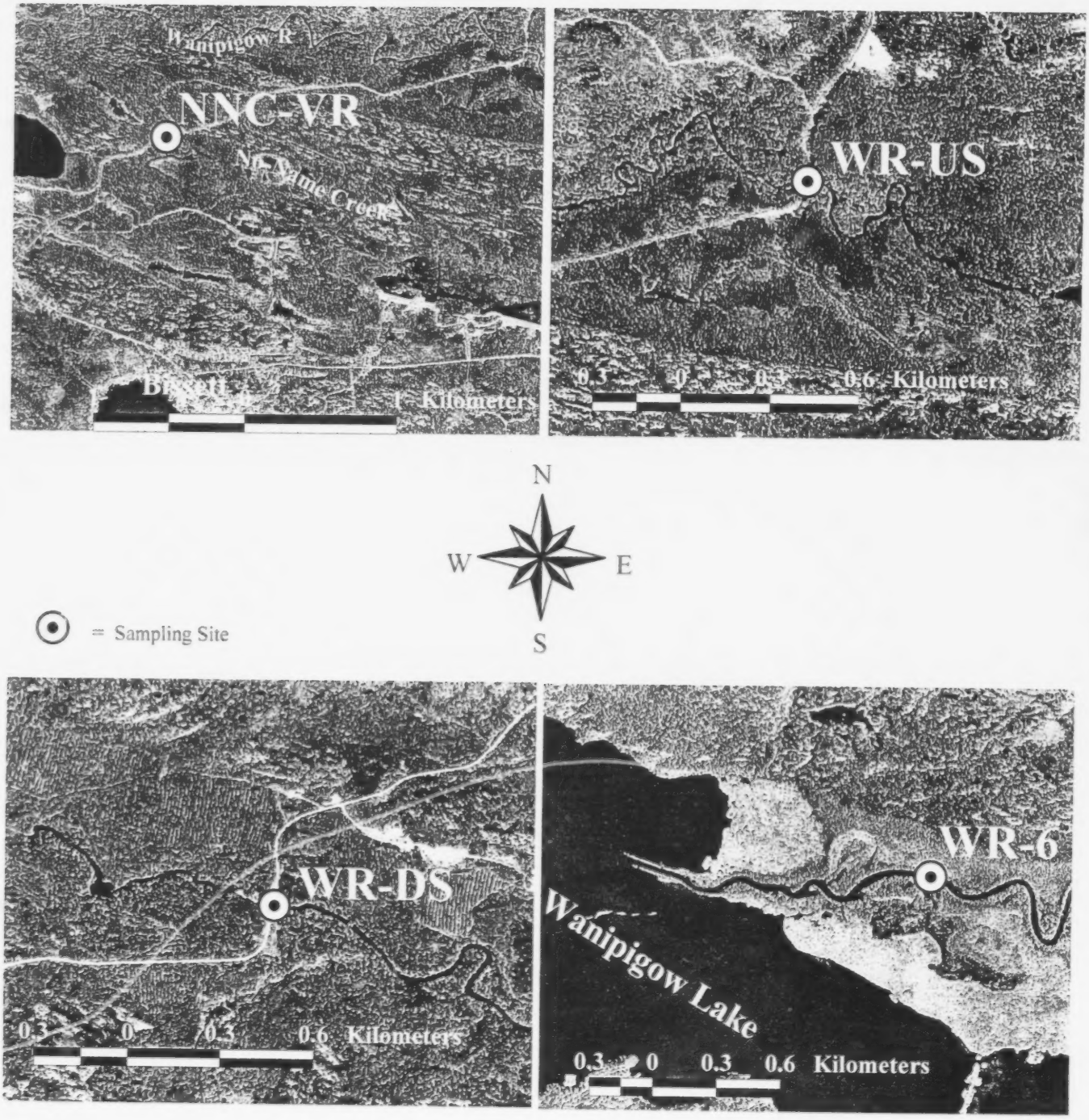
6.0 ACKNOWLEDGEMENTS

I wish to express my sincere appreciation to Mr. Brian Moneyas and Mr. Garf Bushie from the Hollow Water community for their assistance with this project. I would also like to especially thank Mr. Palmi Moneyas for his assistance in collecting water samples from Wanipigow River and Wanipigow Lake.

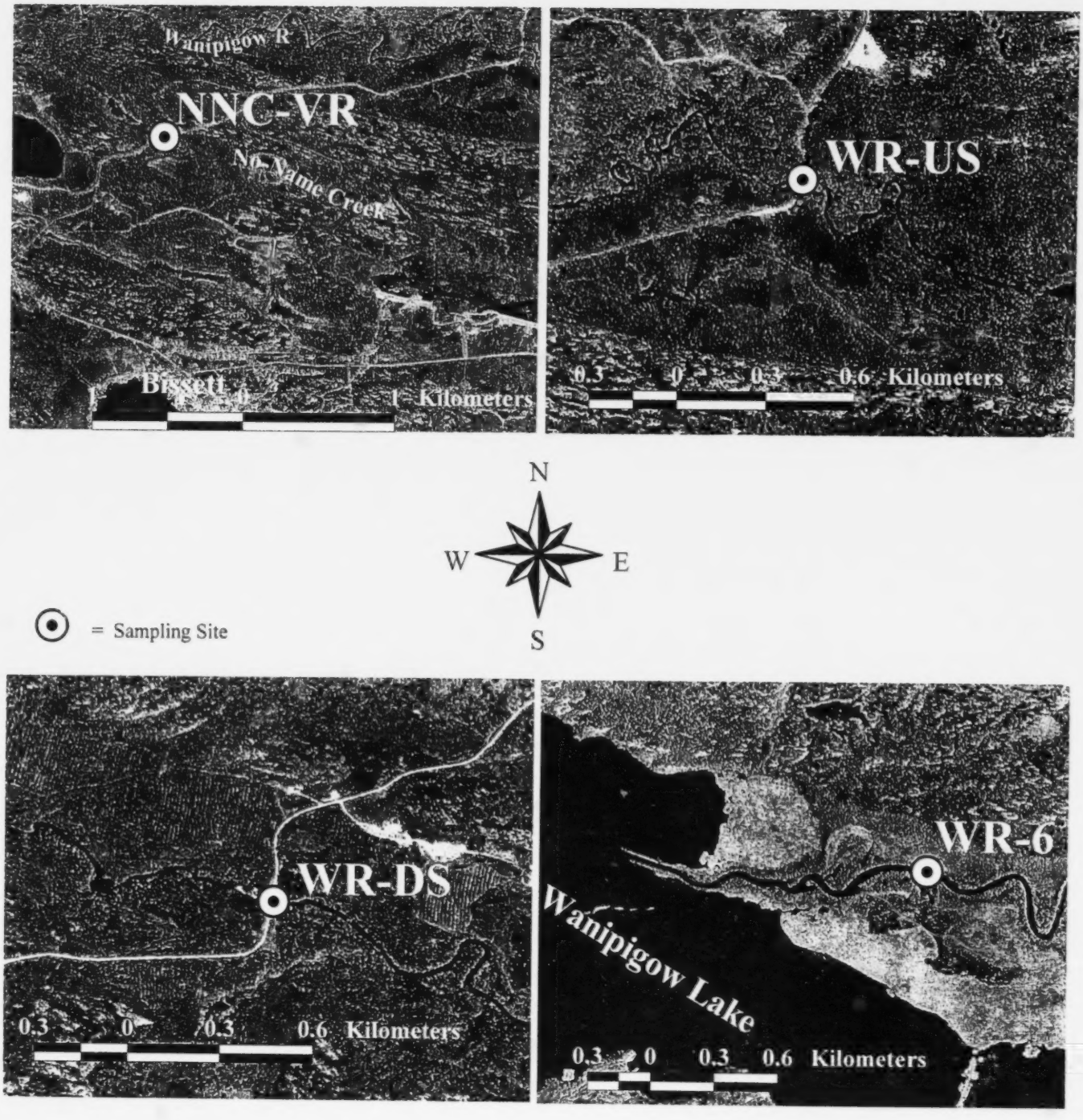
7.0 Appendices



Appendix 1. Aerial photos showing detailed view of water quality sampling sites on the Wanipigow River System, August 2002.



Appendix 2. Aerial photos showing detailed view of water quality sampling sites on the Wanipigow River System, August 2002.



Appendix 2. Aerial photos showing detailed view of water quality sampling sites on the Wanipigow River System, August 2002.

Appendix 3. Synopsis of the relevance of water chemistry variables described in this report.

Summary and Interpretation of Aquatic Variables

Introduction

The following provides a brief synopsis of many of the water quality variables analyzed. The variables are listed alphabetically by name for quick reference. Each variable name is followed immediately by the units of measure in which it is most commonly reported. Also after each variable name is the chemical symbol or formula (in the case of compounds), and in most cases, the most commonly encountered ionized form of the variable in water. A short discussion of the uses, biological importance, potential sources, and general water chemistry of each variable is then summarized. If applicable, each variable summary is followed by a table of objectives and guidelines that have been established for maximum acceptable concentrations of the variable in water. These objectives and guidelines are helpful in that they allow one to determine if the water quality of a surface supply is adequate and safe for the intended use.

Similar to other jurisdictions, Manitoba simultaneously uses two water quality management strategies to provide water quality protection. First, all activities and waste discharges are controlled to the extent that is reasonably practical and economically achievable through a *technology-based approach* for each development sector. Second, a *water quality-based approach* is used when more stringent environmental controls are needed to protect important water uses. Guidance for assessing the quality of water and determining appropriate allowable discharges to water courses has been provided by the Manitoba Surface Water Quality Objectives (**MSWQO**) (Williamson 1988). This document is being replaced by a revised document entitled "Manitoba Water Quality Standards, Objectives, and Guidelines" (**MWQSOG**) (Williamson 2002) in 2003. The **MWQSOG** introduce a three-tiered approach to consolidate and harmonize Manitoba's use of standards, objectives, and guidelines with those developed through other national efforts. They apply to a wider range of water-related media than the **MSWQO** and include surface water, ground water, lake and river bottom sediments, and fish tissues.

Tier I of the **MWQSOG** includes water quality standards for guidance on minimum levels of treatment that must be achieved by dischargers in Manitoba to satisfy the *technology-based approach*, and to be consistent with the pollution prevention principle (*e.g.*, secondary treatment on municipal wastewater effluents to meet minimum standards to not exceed 200 fecal coliform units/100 mL; 30 mg/L Biochemical Oxygen Demand; and 30 mg/L total suspended sediments). Tier I will also include Canada-Wide standards (*e.g.*, petroleum hydrocarbons in soil) being developed by CCME (Canadian Council for the Ministers of the Environment). Tier II includes water quality objectives for a short list of materials that are common pollutants in Manitoba and are generally targeted to be more specific to Manitoba. These objectives provide the basis for the *water quality-based approach*. Similar to the **MSWQO,** Tier II objectives in the **MWQSOG** were based upon the principles advanced by the United States Environmental Protection Agency (US EPA) that healthy ecosystems can tolerate some acceptable stress and can recover. Tier III includes guidelines developed by CCME for numerous materials that may occur in the environment and were derived by CCME to ensure that the most sensitive species likely to occur in Canadian waters are protected at all times along with a margin of safety. Consequently, Tier III guidelines are generally more conservative than Tier II objectives. They

are primarily used to assist in interpreting ambient water quality monitoring data to identify emerging or potential water quality problems. A Tier III guideline may be elevated to a Tier II objective to assist in developing appropriate control strategies for new materials.

Variables

Alkalinity (mg/L)

Alkalinity is an indication of the buffering capacity of the water, which is the ability of the water to neutralize acid inputs. Alkalinity is usually reported as total alkalinity ($CaCO_3$), bicarbonate alkalinity (HCO_3), carbonate alkalinity (CO_3), and hydroxide alkalinity (OH). Although high alkalinity itself is not considered to be harmful, it is usually associated with high pH and high water hardness, as well as excessive dissolved solids.

Aluminum (mg/L) (Al, mainly as aluminum hydroxide, and aluminate ions)

Aluminum is the third most abundant element in the earth's crust. It does not exist in its elemental state in nature, but rather occurs with other elements in a wide range of minerals and ores. Aluminum is used extensively in the manufacture of a variety of lightweight metal alloys. Weathering of rocks and clays is the major natural source of aluminum in surface waters. Aluminum generally enters water in the form of salts, and once dissolved it combines with hydroxide ions (OH^-) to form a variety of ionic forms dependent on the water pH. Industrial effluent and the use of aluminum as a flocculating agent (as alum) are also major contributors of aluminum to surface waters. Flocculation is a method used to settle-out suspended solids and micro-organisms in water. The success of this method in reservoir management is greatly influenced by water pH. Below a pH of 4.0, aluminum is present as hydrated aluminum ($Al(OH)_6^{+3}$); between pH 4.5 to 5.5 and 6.0 to 6.5 it is present as aluminum hydroxide ions ($Al(OH)^{+2}$ and $Al(OH)_2^+$); above 6.5 pH it exists as the aluminate ion ($Al(OH)_4^-$). At pH 5.5 to 6.0, aluminum is least soluble in water, and the aluminum hydroxide ions become colloidal and precipitate out as aluminum hydroxide ($Al(OH)_3$), carrying with them suspended solids, organic compounds, and micro-organisms. Therefore, the greatest success in flocculation is realized when pH is maintained between 5.5 to 6.0. Concentrations of aluminum in surface waters have not been directly linked to any public health problems (including Alzheimer's disease). Ingestion of very large concentrations of aluminum in water can lead to renal and circulatory system problems, but high concentrations are rare and generally related to easily identifiable events such as chemical spills or similar contamination, and excessive effluent output. There are no guidelines for aluminum in domestic water at present, however, guidelines may be proposed in the future.

Aluminum	**Water Use Category**				
(mg/L)	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline		5.0	0.005 & 0.1 *	5.0	

* = Guideline varies with pH, calcium, and dissolved organic carbon concentrations. Guideline value of 0.005 mg/L for pH values < 6.5 units and 0.1 mg/L for pH values > 6.5 units.

Ammonia (mg/L) (NH_3 and NH_4^+)

Ammonia is an inorganic form of nitrogen that can be used directly for use by plants. Nitrogen itself is one of the three main macro-nutrients required by plants, and inadequate levels of a usable form of nitrogen in soil or water can severely limit plant growth and development. Natural sources of ammonia in surface waters include the decomposition of plant material and animal wastes, gas exchange with the atmosphere (pure ammonia being a gas and present in air), weathering of clays, and nitrogen fixation by micro-organisms. Ammonia is a major component in soil fertilizers and significant amounts can enter surface water supplies in run-off from cultivated fields. This can promote excessive growth of algae and other aquatic plants. Ammonia is found in water as NH_3 (an un-ionized form) and as NH_4^+ (an ionized form called ammonium). In water the two forms (NH_3 and NH_4^+) exist in equilibrium and their combined concentration is referred to as total ammonia. This equilibrium is dependent on water pH and temperature, with high pH and temperature causing a shift from $NH_4^+ \longrightarrow NH_3$, and low pH and temperature favouring a shift from $NH_3 \longrightarrow NH_4^+$. In the presence of sufficient dissolved oxygen, ammonia breaks down to form nitrate and nitrite, two forms of nitrogen that are also readily taken-up by plants. The toxicity of ammonia in surface waters is related to the total amount of ammonia present, and in particular the ratio of NH_3: NH_4^+. Ammonia in domestic drinking water is not a problem for humans, however, temperature and pH dependent Manitoba water quality objectives have been established for fish and other aquatic life.

Ammonia	**Water Use Category**				
(mg/L N)	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Objective* pH = 6.5; H_2O temp = 0° C			6.67		
Objective* pH = 6.5; H_2O temp = 30° C			2.46		
Objective* pH = 9.0; H_2O temp = 0° C			0.49		
Objective* pH = 9.0; H_2O temp = 30° C			0.18		

* = Objective changes with pH and temperature. Upper and lower objective values are provided for a combination of upper and lower pH and temperature values.

Note: Values refer to total ammonia and are for chronic exposure of both cool and cold water aquatic life.

Arsenic (mg/L) (As^{+3} and As^{+5})

Arsenic is a metalloid (metal and non-metal characteristics) element that is sometimes present in surface water in trace amounts. The main source of arsenic in surface water is weathering of igneous and sedimentary rocks that contain arsenic. The amount of arsenic in surface waters varies from place to place in accordance with underlying geological formations. Human sewage, industrial effluents, and pesticide run-off also contribute a significant amount of arsenic to surface waters. Arsenic has a relatively complex chemistry in water. Various forms or compounds of arsenic can be present, with certain forms being more chemically reactive than others. In large concentrations, arsenic can be toxic to plant and animal life. It has been shown to accumulate in certain aquatic organisms, and thus chronic exposure to lower concentrations may also cause problems.

Arsenic	Water Use Category				
(mg/L)	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	0.025 (H)	0.025		0.1	
Objective			0.15*		

(H) = Guideline based on health considerations.
* = Objective value based upon dissolved arsenic concentrations.

Barium (mg/L) (Ba^{+2})

Barium is member of the alkaline earth metals group of elements. This group includes such common elements as calcium and magnesium. Barium exists only as an ion in solution (Ba^{+2}) or as a component in minerals and salts. The most common compounds containing barium are minerals barite (barium sulphate $BaSO_4$) and witherite (barium carbonate $BaCO_3$). Barium is fairly common in the earth's crust, but because of the insolubility of barium containing minerals the concentration in surface waters is quite low (usually below 0.6 mg/L in Canada). Barium compounds are used in the manufacturing of plastics, rubber, textiles, electronics, explosives, and ceramics. Compounds are also used extensively as lubricants in the oil and gas industry. Barium can enter surface waters as highly soluble barium salts via industrial waste effluent. Barium is not an essential nutrient for humans, and prolonged exposure at high concentrations can become toxic, resulting in convulsions and paralysis.

Barium	Water Use Category				
(mg/L)	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	1.0 (H)				

(H) = Guideline based on health considerations.

Boron (mg/L) (B)

Boron is a metalloid (metal and non-metal characteristics) element essential, in trace amounts, for flower and fruit development, and hormone movement in plants. It is presently not considered a necessary element in the diet of humans. Weathering of igneous and sedimentary rocks, and leaching of soil all contribute boron to surface waters. Boron has a wide variety of uses in the chemical industry. Perhaps most notably, it is an ingredient in borax, a domestic and industrial cleaning compound and water softener, and as such can readily be passed into surface waters through effluent drainage. Boron occurs in water as the borate ion ($B(OH)^{4-}$) and as weak boric acid salt (H_3BO_3). However, because boric acid has low solubility in water, the tendency for disassociation is also low and free boron ions (B^{+3}) are rare. Boron toxicity can occur at high concentrations, leading to diarrhea, headaches, vomiting, kidney problems, and possibly sterility. Boron concentrations in surface waters in Canada generally fall below 0.5 mg/L.

Boron	Water Use Category				
(mg/L)	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	5.0 (H)	5.0		0.5 - 6.0	

(H) = Guideline based on health considerations.

Cadmium (mg/L) (Cd^{+2})

Cadmium is a metallic element found in small amounts in the earth's crust; usually associated with zinc, lead, and copper ores. Cadmium has a number of industrial applications such as metal plating, and is an important ingredient in nickel-cadmium storage batteries, solders, and electrical equipment. Pathways into surface water include weathering of cadmium containing igneous rocks and shales, emissions and effluent from the mining industry, run-off from agricultural lands (found in some pesticides), and the burning of fossil fuels. In general, only trace amounts (< 0.001 mg/L) of cadmium are found in surface water supplies. The form, chemistry, and solubility of cadmium in surface water is complex and is influenced by pH, hardness (calcium and magnesium), and the presence of other metal ions. Food is the main source of cadmium intake by humans. Chronic long-term exposure to cadmium can cause gastrointestinal problems, bone deterioration, and kidney disease. There have been no concrete links made between cancer in humans and cadmium consumption, however, research into this area continues. Because cadmium is found in food, it is important to minimize the amount ingested through drinking water, and thus minimize the total cadmium in one's diet.

Cadmium	**Water Use Category**				
(mg/L)	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	0.005 (H)	0.08		0.0051	
Objective			0.0008 & 0.0003*		

(H) = Guideline based on health considerations.

* = Objective changes with water hardness ($CaCO_3$ mg/L) concentrations where increasing hardness increases the ability for higher objective values. The listed values are for chronic exposure to dissolved cadmium concentrations and for hardness concentrations of 25 and 150 mg/L, respectively.

Calcium (mg/L) (Ca^{+2})

Calcium is often the most abundant dissolved element in surface water supplies. This is due to its abundance on the earth's surface (it is a major constituent of limestone rock) and the fact that it is readily dissolved from rocks and leached from the soil by water. Calcium is essential for bone growth and maintenance in vertebrates and cell wall and cell membrane structure in plants. When dissolved in water calcium exists as the calcium ion (Ca^{+2}). This calcium ion is strongly electropositive and easily attracts negatively charged ions to form salt compounds (*e.g.*, calcium carbonate $CaCO_3$) which precipitate out of solution. High water temperatures enhance this activity. Thus, in most instances the concentration of calcium ions in solution tends to decrease during the summer and increase in the fall and winter. Levels of calcium in surface waters of western Canada range from 0.28 mg/L to 67.0 mg/L. There is no established guideline or water quality objective for maximum acceptable calcium concentration in human drinking water. High levels of calcium, in company with magnesium, contribute to increased hardness of the water and high pH values.

Carbon, Total (mg/L) (C)

Carbon is the most common element in all, living organisms. Along with hydrogen and oxygen it forms carbohydrates (sugars, starch, cellulose) which account for up to 96% of the dried weight of plant material. Total carbon is the sum of all inorganic and organic forms of

carbon in the water. Carbon sources in water include decaying plant and animal material, effluent from industry, human sewage, agricultural run-off, weathering of carbonate rock, plant and animal respiration, and gas exchange with the atmosphere. Presently, there are no guidelines or objectives for total carbon in surface water.

Carbon, Total Inorganic (mg/L) (C)

Total inorganic carbon (TIC) is a measure of the amount of carbon present in inorganic compounds in water. Some of the major inorganic carbon compounds in water include carbonates (*e.g.*, calcium carbonate - $CaCO_3$), bicarbonates (*e.g.*, sodium bicarbonate $NaHCO_3$), and carbonic acid (H_2C0_3). These inorganic carbon compounds usually dissolve quite readily in water and have a strong influence on water hardness, pH, and alkalinity. Sources of inorganic carbon include weathering of limestone and dolomite rock, which contain magnesium and calcium carbonates, and carbon dioxide from respiring organisms and the atmosphere. Presently, there are no guidelines or objectives for TIC in surface water.

Carbon, Total Organic (mg/L) (C)

Total organic carbon (TOC) refers to the amount of carbon in organic material in the water, and as such is an overall indicator of the organic content of the water. TOC can occur in both dissolved and particulate forms. The main sources of TOC in surface waters are photosynthesis and decaying plant and animal tissue. Domestic sewage, effluent from certain industries (*e.g.*, pulp and paper), and agricultural run-off can also contribute organic carbon to surface waters. Shoreline erosion, plant productivity, and the specific composition of the organic material (the amount of carbon depending on the type of material present) effect the concentrations of TOC in water. At present, there are no guidelines or objectives for TOC in surface water. However, steps should be taken to reduce levels as much as possible as the amount of TOC in water has a direct effect on the amount of oxygen in the water. Dissolved oxygen is consumed as organic material is decomposed. Thus, water high in TOC concentrations can become anaerobic (oxygen depleted), which can affect fish and other aquatic organisms, as well as create taste and odour problems. Artificial aeration of the water can help to alleviate this problem. High organic carbon concentrations have also been linked to increased formation of trihalomethanes in water disinfected with chlorine.

Chloride (mg/L) (Cl^-)

Chloride is the negatively charged ion of chlorine. Chloride is an essential element for both animal and plant life. In combination with positively charged ions, chloride forms such salts as sodium chloride (common table salt), potassium chloride (potash), and calcium chloride (road salt). The relatively high water solubility of chloride salts makes them important and useful substances for the chemical and agricultural industry. Concentrations of chloride in surface waters are usually <10 mg/L under natural conditions. However, chlorides usually increase with the use of chlorine as a disinfectant or bleaching agent, and with the use of water softening salts. As well, saline groundwater intrusion may occur in certain areas. High chloride levels in drinking water are not considered a health concern, but may result in taste problems and can adversely affect sensitive aquatic plant species.

Chloride	Water Use Category				
(mg/L)	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	250 (A)			100 - 700	

(A) = Guideline based on aesthetic considerations.

Chlorophyll-*a* (µg/L)

Chlorophyll-*a* is a pigment found within all green plants, including algae. It is crucial for plant growth because it absorbs light, thereby providing energy for photosynthesis. In the case of algae, chlorophyll-*a* comprises a large portion of the algal cell mass. Therefore, the amount of chlorophyll-*a* in a water sample is a good indicator of the amount of algae present in the water. There is no maximum acceptable guideline established for chlorophyll-*a* concentration in drinking water. However, a high concentration may be indicative of other problems such as high nitrogen and phosphorus concentrations. Also, high concentrations of chlorophyll-*a* often occur concurrently with poor tastes, displeasing odours and colouration, and clogged filtration systems. Decomposition of large algal blooms may deplete the oxygen supply in water, leading to anaerobic conditions.

Chromium (mg/L) (Cr^{+6} (hexavalent chromium or chromium (VI)))

Chromium is a white, lustrous, hard metal that is very resistant to corrosion. This makes it very useful as a protective and decorative coating for other metals such as brass, bronze, and steel. It is also used extensively in the production of paints, dyes, explosives, ceramics, and paper, and in some fertilizers and pesticides. Major pathways for chromium into surface water include the weathering of chromium minerals such as chromite ($FeCr_2O_2$), and industrial emissions. Chromium can exist in a number of ionic states in water, but chromium (III) (trivalent chromium - Cr^{+3}) and chromium (VI) (hexavalent chromium - Cr^{+6}) are the most common. Chromium (III) is actually considered an essential element for protein, sugar, and lipid metabolism in humans and other animals. Because of this it is considered non-toxic, but can in water, be converted to the toxic chromium (VI), if the water is chlorinated. Research has yet to show a clear link between cancer and chromium intake. However, prolonged exposure to chromium (VI) can cause gastrointestinal, liver, and kidney problems. Laboratory analysis is concerned with determining the concentration of chromium(VI) because it is the toxic form of the element in water. Concentrations in Canadian surface waters are generally low; ranging from <0.001mg/L to 0.044 mg/L for total chromium, and <0.001 mg/L to 0.023 mg/L for chromium (VI).

Chromium(VI) (hexavalent)	Water Use Category				
(mg/L)	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline		0.05		0.008	
Objective			0.011		

Chromium (III)	Water Use Category				
(mg/L)	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline		0.05		0.0049	
Objective			0.024 & 0.103*		

* = Objective changes with water hardness ($CaCO_3$ mg/L) concentrations where increasing hardness increases the ability for higher objective values. The listed values are for chronic exposure to dissolved chromium III concentrations and for hardness concentrations of 25 and 150 mg/L, respectively.

Cobalt (mg/L) (Co^{+2}, Co^{+3})

Cobalt is a hard, bluish white metal used to impart strength, wear, and corrosion resistance in metal alloys. Cobalt is a constituent of vitamin B_{12}, which is required by animals for proper enzyme activity. Most plants, with the exception of some green and blue-green algae, do not require cobalt as a nutrient for growth. Cobalt enters surface water through weathering of rocks. It is usually associated with minerals containing nickel, sulphur, arsenic, and copper. Thus, it also enters the aquatic environment through mining and industrial emissions and effluent. Cobalt exists in a number of states in nature, but in water is predominantly present in its cobaltous (Co^{+2}) and cobaltic (Co^{+3}) forms. The cobaltous form combines with water molecules to form the relatively stable, pink coloured $Co(H_2O)_6^{+2}$ ion, while the cobaltic form is less stable and rapidly converts to the cobaltous form or combines with negatively charged elements to form complex particles in solution. At present there is no maximum acceptable guideline for cobalt in human drinking water. Generally levels in drinking water are very low (*i.e.*, <0.002 mg/L), and the majority of human intake is via meat and dairy products.

Cobalt	Water Use Category				
(mg/L)	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline		1.0		0.05	

Coliform Bacteria, Fecal (fecal coliform units/100 ml)

Fecal coliforms are a group of bacteria comprised of *Escherichia coli* (more commonly referred to as *E. coli)* and species of the genus *Klebsiella*. Both *E. coli* and *Klebsiella* spp. occur naturally in the intestinal tract of birds and mammals. *Klebsiella* spp. may also be found in organic-rich effluents such as those from pulp and paper operations. Fecal coliforms are important because they can indicate the presence of other disease-producing organisms. High numbers of fecal coliform bacteria in water generally indicates the presence of non-disinfected fecal matter. Sources of fecal coliform bacteria include feces from humans, livestock, and wildlife. The presence of fecal coliform bacteria is considered unacceptable in drinking water. As with total coliforms, fecal coliform levels in drinking water can usually be controlled by disinfection methods. Lab results of <1 organism/100 mL indicate no fecal coliforms were found in the water sample.

Fecal Coliform Bacteria or Escherichia coli (number/100 mL)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Objective	0 (H)			200	200 *

(H) = Objective based on health considerations.
* = Recreational activities such as swimming.

Colour (True Colour Units)

The primary concern for colour in drinking water is one of aesthetics. Colour itself is not harmful, but high values are considered aesthetically unpleasant, and are indicative of excessive levels of organic matter and/or metals (*e.g.*, iron, manganese, and copper).

Colour (True Colour Units)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	15 (A)				

(A) = Guideline based on aesthetic considerations.

Conductivity (µS/cm @ 25 °C)

Conductivity is an indirect measure of the dissolved salt or mineral content in the water. Conductivity is measured by passing an electrical current through the sample. The higher the concentration of dissolved materials in the water, the higher the electrical conductivity. Thus, conductivity is very low in distilled water, and high in saline, alkaline, and hard water. There are presently no domestic consumption guidelines or objectives for conductivity.

Conductivity (µS/cm)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Objective				1000 – 1500*	

* = Objective of 1000 µS/cm is for periods when greenhouse irrigation is likely to occur, while 1500 µS/cm is for periods when field, park, and garden irrigation is likely to occur.

Copper (mg/L) (Cu^{+2})

Copper is a metallic element that can occur in nature in pure form, but is more often found associated with other metals in mineral complexes. It is an essential element for certain enzymatic processes in plants and animals. Copper is used extensively in the production of electrical wire, piping, and numerous metal alloys. It is also an important constituent in pesticides used to protect and preserve wood and to control algae and other plant growth in water supplies used for drinking. Weathering of rocks and minerals, corrosion of brass and copper pipes, run-off from cultivated fields, the use of copper compounds as algaecides, and sewage plant and mining effluents are the most common pathways for copper into surface water supplies. In non-polluted surface waters in Canada copper concentrations rarely exceed 0.05 mg/L. The chemistry of copper in water is very complex and not fully understood. Generally, if

present in water it is as the cupric ion (Cu^{+2}). However, the concentration of these ions is strongly influenced by water pH. At pH levels above 6.5, cupric ions tend to precipitate out of solution as $Cu(OH)_2$ or combine with carbonates, oxides, and sulphides to form colloidal suspensions or precipitates. High concentrations of copper can lead to corrosion of zinc and aluminum, staining of laundry and bathroom fixtures, and may impart a bitter taste to drinking water. Copper is toxic to humans only at very high concentrations.

Copper	**Water Use Category**				
(mg/L)	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	1.0 (A)	0.5 - 5.0		0.2 – 1.0	
Objective			0.0027 & 0.013 *		

(A) = Guideline based on aesthetic considerations.

* = Objective changes with water hardness ($CaCO_3$ mg/L) concentrations where increasing hardness increases the ability for higher objective values. The listed values are for chronic exposure to dissolved copper concentrations and for hardness concentrations of 25 and 150 mg/L, respectively.

Hardness (mg/L)

Hardness is a measure of the positively charged ions dissolved in water. Calcium (Ca^{+2}) and magnesium (Mg^{+2}) are the main contributors to water hardness because of their high concentrations in nature. High hardness values result from water draining through carbonate rock and other calcareous materials that are high in calcium and magnesium. Water with hardness levels ranging from 0 mg/L to 30 mg/L is considered soft, while levels in excess of 180 mg/L are characteristic of very hard water. Hardness influences the form and toxicity of some heavy metals. Hard water can be treated with a softener, but this will result in elevated chloride and sodium or potassium levels in the water. A surface water quality objective of 200 mg/L has been recommended for domestic consumption in Manitoba based on aesthetic considerations. No other guidelines or objectives have been proposed.

Iron (mg/L) (Fe^{+2}, Fe^{+3})

Iron is the fourth most common element in the earth's crust. It is a heavy metal that is essential for photosynthesis in plants and production of hemoglobin in red blood cells of humans. Iron is naturally released to surface waters through weathering of iron bearing minerals, but significant amounts are also released through industrial processes, corrosion of iron and steel, and discharges from mining operations. Iron concentrations in freshwater on the Canadian prairies can range as high as 14 mg/L. However, this condition is rare. Levels of iron in water above 0.3 mg/L can lead to staining of laundry and plumbing fixtures, while higher concentrations can impart a metallic taste and yellow precipitate in the water. If concentrations exceed 0.5 mg/L, it may interfere with zeolite water softening. Excessive levels of iron in water may also indicate environmental stresses such as acidification and anaerobic conditions (*i.e.*, lack of oxygen).

Iron	**Water Use Category**				
(mg/L)	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	0.3 (A)		0.3	5.0	

(A) = Guideline based on aesthetic considerations

Lead (mg/L) (Pb)

Lead is a common heavy metal found in the earth's crust. It is found in at least 200 different minerals, most of which are rare, with the exception being the mineral galena. Lead is used in the production of storage batteries and is an important ingredient in the manufacture of numerous chemical compounds used in a variety of industries. Weathering of minerals containing lead is the main natural pathway for entering surface waters. Significant amounts of lead are also released in metal smelting emissions, and mine and industrial effluents. The North American ban on lead based additives to automotive fuel eliminated the formerly high emissions from automobile exhaust. Levels of dissolved lead in natural surface waters are generally quite low (0.001 mg/L to 0.050 mg/L in Canadian waters). The chemistry of lead in the aquatic environment is relatively complex and not fully understood. Lead tends to bind with organic material to form soluble, colloidal (suspended), and particulate compounds. Dissolved oxygen, hardness, pH, and the concentration and composition of inorganic and organic matter all appear to affect the concentration of lead in surface water. Lead is bioaccumulated (stored in tissues and organs) by plants and animals, and can have toxic effects on organisms that experience prolonged exposure, even at low concentrations. The Health Canada maximum acceptable concentration guideline for lead in drinking water is 0.01 mg/L. This guideline is based on long-term exposure and concentrations slightly or periodically above the guideline may not necessarily pose a health risk.

Lead	**Water Use Category**				
(mg/L)	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	0.01 (H)	0.1		0.2	
Objective			0.0005-1 & 0.0039*		

(H) = Guideline based on health considerations.

* = Objective changes with water hardness ($CaCO_3$ mg/L) concentrations where increasing hardness increases the ability for higher objective values. The listed values are for chronic exposure to dissolved lead concentrations and for hardness concnetrations of 25 and 150 mg/L, respectively.

Magnesium (mg/L) (Mg^{+2})

Like calcium, magnesium is an abundant element in surface water supplies. Weathering of igneous and sedimentary rock (*e.g.*, dolomite), in which it is a common constituent, are the main natural sources of magnesium in surface waters. Significant contributions to surface waters can also originate via effluent from chemical and textile manufacturers, tanneries, and cement plants. Magnesium is an essential element for enzymatic activity and protein synthesis in plants and animals. It is also an important component of chlorophyll in plants. Levels of magnesium in surface waters of western Canada range from 0.03 mg/L to 168.0 mg/L. There are no drinking water guidelines for magnesium. However, along with calcium, it is a major contributor to water hardness. Water with high levels of magnesium (>150 mg/mL) can have taste problems, and prolonged consumption may cause diarrhea.

Manganese (mg/L) (Mn^{+2})

Manganese is a heavy metal that is essential, in trace amounts, for the normal growth and development of plant and animal life. Natural sources of manganese in water result from weathering of mineral deposits, where it is often associated with iron. As such, manganese levels in surface waters are usually closely correlated with iron levels. High levels of manganese in drinking water result in taste problems, staining of plumbing fixtures, and may promote the growth of certain micro-organisms in treatment systems. Manganese is usually present in surface waters at concentrations less than 1.0 mg/L.

Manganese	Water Use Category				
(mg/L)	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	0.05 (A)			0.2	

(A) = Guideline based on aesthetic considerations.

Microcystin-LR (µg/L) (Blue-green algae toxin)

Microcystin-LR is a metabolic by-product of certain blue-green algae species. It is a hepatotoxin in that it damages or destroys liver function in animals.

Blue-green algae, (cyanobacteria) are common in all fresh water environments. However, extensive growths of blue-green algae generally only occur in nutrient enriched waters (high phosphorus and nitrogen concentrations) during periods of hot and calm weather. Since warm water allows the growth rate to increase, blooms of blue-green algae are often experienced in mid to late summer. Blooms may last anywhere from a few days to several weeks. Only a few species of blue-green algae are known to produce toxins. Hepatotoxins, such as microcystin-LR, cause necrosis of the liver, which can result in death by hemoraphagic shock or liver failure within a few hours to a few days depending on the concentration of the toxin in water, the size of the animal, and the amount of water consumed. In Manitoba 135 of the 290 municipal drinking water supplies are derived from surface water sources. In addition, approximately 15,000 farm dugouts are utilized as domestic and livestock water supplies. Most of these surface sources are vulnerable to nutrient enrichment and the subsequent formation of blue-green algal blooms. Farmers experience economic losses when livestock die or become ill from toxic algae ingestion, while consumption of domestic and municipal water supplies containing algal toxins poses a potential health risk to humans.

Control of toxin producing blue-green algae is difficult. Research has indicated that the presence or absence of odour in water cannot be used as an indicator for the presence of microcystin-LR. As well, because the toxin itself may persist in water for over three weeks following an algal bloom, a direct correlation between the population size of blue-green algae and the concentration of microcystin-LR is often not apparent. The use of algaecides (*e.g.*, blue-stone) is not recommended once a bloom has formed since it may result in the immediate release of more toxins from dead and dying cells. Boiling of drinking water is not recommended as a treatment because it does not denature the toxin, and again, may result in the release of the toxin as cells are killed. Studies in Alberta and Saskatchewan, where the occurrence of microcystin-LR and other blue-green toxins is very prevalent, have investigated flocculation and liming as possible control methods for blue-green algae in small reservoirs. Health Canada has recommended and interim guideline of 1.5 µg/L for microcystin-LR in drinking and recreational waters. No other guidelines or objectives exist at the present time.

Microcystin-LR	Water Use Category				
(µg/L)	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	1.5 (H)				

(H) = Guideline based on aesthetic considerations.

Molybdenum (mg/L) (Mo^{+6})

Molybdenum is a metallic element that is widely distributed geographically, but in relatively low concentrations. It can occur in a number of different compounds, but is most commonly associated with sulphur in the mineral molybdenite (MoS_2) and in molybdate (MoO_4^{-2}) minerals. Weathering of igneous rocks and sedimentary shales is the natural pathway by which molybdenum enters the aquatic environment. Mining, the burning of fossil fuels, and run-off from cultivated land also contribute significant amounts of molybdenum to surface water. In water, the mineral molybdenite is insoluble, but it is usually rapidly converted to the soluble molybdate ion (MoO_4^{-2}) which is stable in solution. Molybdenum is taken-up by nitrogen-fixing plants such as legumes and some algae species as the molybdate ion. It is a necessary element in the process of nitrogen fixation by such plants, and, if not available, nitrogen deficiency symptoms will develop. Concentrations of molybdenum in surface waters in Canada rarely exceed 0.001 mg/L. At present there is no guideline or objective for molybdenum in domestic water supplies.

Molybdenum	Water Use Category				
(mg/L)	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline		0.5	0.073	0.01 - 0.05	

Nickel (mg/L) (Ni^{+2})

Nickel is the 23rd most abundant element in the earth's crust. It is commonly found in mineral deposits in association with antimony, arsenic, and sulphur. Nickel is a very important economic metal since it is used in the production of storage batteries, coins, and stainless steel and other corrosion resistant metal alloys. The majority of nickel production comes from sulphide minerals such as pentlandite ($(FeNi)_9S_8$). Large pentlandite deposits are found near Sudbury, Ontario, making it one of the largest, nickel producing regions in the world. Nickel enters surface water primarily through weathering of rocks and minerals, the burning of fossil fuels, and in mining wastewater. The occurrence of nickel in water results from the disassociation of soluble nickel salts. Nickel can occur in a number of ionic forms in water, but the most common form is as Ni^{+2}. Nickel can also combine with or become adsorbed to carbonates, iron and manganese oxides, silica, suspended particulate matter, and organic material in water. The solubility of nickel in water is influenced by pH and water hardness. Generally, pH values above 6.0 result in reduced concentrations of nickel in the water column. Concentrations of nickel in non-polluted surface waters in Canada are usually around 0.001 mg/L to 0.002 mg/L. However, nickel is bioaccumulated by some aquatic plants and animals, including fish. A guideline for nickel in human drinking water is under review by Health Canada.

Nickel	Water Use Category				
(mg/L)	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline		1.0		0.2	
Objective			0.016 & 0.073 *		

* = Objective changes with water hardness ($CaCO_3$ mg/L) concentrations where increasing hardness increases the ability for higher objective values. The listed values are for chronic exposure to dissolved nickel concentrations and for hardness concentrations of 25 and 150 mg/L, respectively.

Nitrate-Nitrite (mg/L) (NO_3^-, NO_2^-)

Nitrate (NO_3^-) and nitrite (NO_2^-) are two inorganic forms of nitrogen found in surface water. Along with ammonia, they are a very important source of nitrogen for aquatic plants. Nitrates are used extensively as an ingredient in nitrogen fertilizers. Thus, water run-off from cultivated land is a major source of nitrates in surface waters. Nitrates can also be added to surface waters through the decomposition of plant material and animal wastes, and leachate from igneous rocks. Generally, nitrate levels in surface waters in western Canada rarely exceed 5 mg/L, and are usually below 1 mg/L. Nitrite is also found in surface waters, but usually at levels much lower than nitrate. Nitrite concentrations in natural settings are usually around 0.001 mg/L. Sources of nitrite include industrial effluents and animal waste. High levels of nitrates-nitrites in municipal or farm water supplies in rural Manitoba are usually a sign of poor sewage treatment and/or run-off from cultivated land (excessive crop fertilization) and feedlots/pastures. The maximum acceptable drinking water guideline set by Health Canada is 10.0 mg/L for nitrate (reported as nitrogen) and 1.0 mg/L for nitrite (reported as nitrogen). In combination (nitrate-nitrite reported as nitrogen), the concentration should not exceed 10.0 mg/L. Concentrations of nitrate-nitrite (as nitrogen) above 10.0 mg/L may result in 'blue baby' condition (methemoglobinemia) in infants, which, under certain conditions and prolonged exposure, can be fatal.

Nitrate-Nitrite	Water Use Category				
(mg/L N)	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline		100.0			
Objective	10.0 (H)				

(H) = Objective based on health considerations.

Nitrogen - Total Kjeldahl (mg/L) (N in organic compounds and NH_3)

Kjeldahl (pronounced 'kell-dall') nitrogen is a measure of the sum of organic nitrogen and ammonia in a water body. By subtracting the amount of ammonia in the water one can calculate the amount of nitrogen that is bound up in organic molecules in live and dead aquatic organisms. Thus, total Kjeldahl nitrogen (minus ammonia) is indicative of the amount of biological productivity in a surface water supply. A maximum acceptable concentration guideline for total Kjeldahl nitrogen has not been set, however, guidelines are available for the inorganic forms of nitrogen; namely ammonia, nitrate, and nitrite.

Oxygen (mg/L) (O_2)

Oxygen, a gaseous element, is a requisite for most life on earth. Exceptions include a number of anaerobic bacteria species which are adapted to living in oxygen depleted habitats. Elemental oxygen is very reactive, and oxygen gas itself is composed of two tightly bound oxygen atoms (O_2). Sources of dissolved oxygen include the atmosphere and plant photosynthesis. Oxygen is moderately soluble in water, with the solubility affected by temperature, salinity, turbulence (mixing), and elevation (atmospheric pressure variations). Solubility decreases as temperature, salinity, and elevation increase, and turbulence decreases. Decomposition of plant and animal material by bacteria and plant and animal respiration use up large quantities of dissolved oxygen. If inputs of oxygen are not kept in balance with oxygen consumption rates, then anaerobic (oxygen depleted) conditions may result. This can create odour and taste problems and affect the overall chemistry of the water body. There is no guideline or objective for oxygen in human or livestock drinking water or in irrigation water. However, to avoid anaerobic conditions and support aquatic life, it is recommended that oxygen levels be maintained between 5.0 and 9.5 mg/L (or 47 % to 60 % saturation depending on temperature). In the case of dugouts, this can usually be achieved through artificial aeration.

pH (pH units)

Water pH is a measure of the concentration of hydrogen ions (H^+) in the water. The concentration of H^+ in water determines the water's acidity. The pH is measured on a negative logarithm scale from 0 to 14. Therefore, the lower the pH value for a water sample, the higher the concentration of H^+ and the more acidic the water. A pH value of 7.0 units is neutral, while those above 7 are basic (*i.e.*, alkaline). Knowledge of pH is important as it influences the concentration of a number of trace metals and the productivity of aquatic organisms. As well, chlorination of water for disinfecting purposes is less successful if pH is above 8.5. The pH can vary throughout the year, and guidelines and objectives are shown as ranges. Maintenance of pH within the guideline and objective ranges should be an important goal for all surface water supplies.

PH	**Water Use Category**				
(pH units)	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	6.5 - 8.5 (A)		6.5 - 9.0		5.0 - 9.0

(A) = Guideline based on aesthetic considerations

Phosphorus, Total (mg/L) (P in a variety of inorganic and organic forms)

Phosphorus is an essential mineral nutrient for plant and animal life. In both cases it is a component of adenosine triphosphate (ATP), the molecule used in the storage and transfer of energy in living organisms. It is also important in the maintenance and growth of bone and teeth in humans. In aquatic settings it is often the nutrient which is most important in determining the overall productivity of the ecosystem. Phosphorus is a very reactive element and in nature always exists with other elements to form organic or inorganic compounds. The total phosphorus in water is a summation of dissolved forms, forms adsorbed to sediment particles, and compounds contained in the cell walls of aquatic plants and animals. Phosphorus

compounds are released into surface water through weathering of soil and rock and the decomposition of organic material. Domestic and industrial sewage and run-off from fertilized cultivated lands and livestock areas also contribute significantly to the total phosphorus in surface waters. However, because it is rapidly taken-up and assimilated by organisms, phosphorus concentrations under natural conditions tend to be low. High concentrations of phosphorus have not been shown to be toxic to humans. In combination with other factors, high levels of phosphorus can result in excessive algae, fungal, and macrophyte (aquatic weeds) growth. Total phosphorus levels below 0.025 mg/L in lakes, ponds, and reservoirs, and less than 0.05 mg/L in rivers and streams usually do not result in excessive algae or macrophyte growth.

Phosphorus, Dissolved (mg/L) ($H_2P0_4^-$, $HP0_4^{-2}$, $P0_4^{-3}$)

The dissolved phosphorus content of water refers to that portion of the total phosphorus content that is present in the water after filtration (0.45 microns). Generally these are phosphate ions that are not bound to suspended particulate matter or tied-up in living organisms. The most common ionic forms of phosphate found in water include phosphate ($P0_4^{-3}$), dihydrogen phosphate ($H_2P0_4^-$), and monohydrogen phosphate ($HP0_4^{-2}$). It is these forms, often referred to as orthophosphates that are available for up-take by plants. The concentration of dissolved phosphate ions in water is influenced by water pH, the activities of fungi, bacteria, algae, and invertebrates, and the concentration and composition of trace metals, organic compounds, and other particulate matter.

Potassium (mg/L) (K^+)

Potassium is a major mineral element common in clay and sedimentary shales. Along with nitrogen and phosphorus, it is one of the most important plant nutrients. It is essential for enzyme activity and the maintenance of turgor pressure, without which plants develop weak stem and root systems. It is also necessary for proper osmotic balance and nerve function in higher animals. Most potassium in surface waters originates from leaching and weathering of soils that release potassium salts. Potassium salts are generally very soluble in the aquatic environment, therefore potassium is found mainly in the ionic form (K^+) in water. Concentrations of potassium in surface waters rarely exceed 20 mg/L, although ranges as high as 33.0 mg/L have been recorded in western Canada. There are no maximum acceptable guidelines or objectives for potassium in surface water supplies. However, although one is very unlikely to encounter it in a natural setting, levels above 2000 mg/L can be toxic to humans.

Selenium (mg/L) (Se^{+4}, Se^{+6})

Selenium is a metallic element that is widely distributed in the earth's crust at low concentrations. It is used in the production of electrical components, metallurgical industries, glass and ceramic production, and the manufacture of certain pharmaceuticals. In Canada, it is used mainly in glass making (73%). Selenium is usually obtained as a by-product of copper smelting and refining. Canada is one of the world's biggest producers of selenium. Weathering of rocks and minerals is the main pathway for selenium into the aquatic environment. There is also some evidence that burning of fossil fuels and mining and smelting emissions contribute

some selenium to surface waters. Selenium is a relatively reactive element, and can exist in a number of states. Se^{+4} and Se^{+6} are the two most common forms of selenium in water. The two forms tend to combine with oxygen in water to form the soluble ions selenite oxyanion (SeO_3^{-2}) and selenate oxyanion (SeO_4^{-2}). Pure or elemental selenium (Se) is insoluble in water, and tends to settle out and accumulate in sediments. Selenium is an essential element for some plants and higher order animals. However, only trace amounts are required, and prolonged ingestion of higher concentrations can become toxic. Selenium levels in most Manitoba surface waters fall below 0.005 mg/L, and no supplies have been found that exceeded the human drinking water guideline.

Selenium	**Water Use Category**				
(mg/L)	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	0.01 (H)	0.05	0.001	0.02 - 0.05	

(H) = Guideline based on health considerations.

Silver (mg/L) (Ag^+)

Silver is one of the least abundant metallic elements in the earth's crust. Silver can be found as elemental (pure) silver in nature, but more often than not, it occurs associated with other elements in mineral compounds. It is fairly widely distributed, but is found generally in very low concentrations. However, the unique characteristics of silver (its high luster when polished, sensitivity to light, and high thermal and electrical conductivity) make mining activities economical. Silver is used predominantly in the production of photographic materials, coinage, sterling and silver plated wares, jewellery, mirrors, dental and medical supplies, solders, some fungicides, and electrical components and batteries. Its main pathway into the aquatic environment is through weathering and volcanic activity. Silver also enters the environment through landfills and wastewater, and emissions from mining, iron and steel manufacturing, and crude oil production. Silver is not very soluble in water, but if present is usually in the form Ag^+. Natural concentrations of silver in Canadian surface waters tend to be less than 0.01 mg/L. However, concentrations of 0.04 mg/L have been reported in waters subjected to industrial effluent or sewage inflow. Silver tends to bioaccumulate in aquatic organisms, and may, over time, become toxic.

Silver	**Water Use Category**				
(mg/L)	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline			0.0001		

Sodium (mg/L) (Na^+)

Sodium is the sixth most common element in the earth's crust. Sodium is essential for nerve function and water balance in higher animals, but is usually a deterrent to proper growth and development in plants. Weathering of salt rock deposits is the main natural source of sodium in surface water. Concentrations in surface waters, therefore, can vary greatly geographically because of spatial variation in mineral deposits. Prolonged exposure to

concentrations above the guideline and objective can be a factor in kidney, circulatory, and heart diseases in humans. Consultation with a physician is recommended for those on restricted sodium diets whose drinking water approaches or surpasses the guideline or objective. It should be noted that some water softeners, used to reduce water hardness, will increase the levels of sodium in drinking water.

Sodium	**Water Use Category**				
(mg/L)	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	200 (H)				

(H) = Guideline based on health considerations.

Sulphate (mg/L) (SO_4^{-2})

Sulphate is a negatively charged ion composed of one atom of sulphur and four atoms of oxygen. Sulphur, in low concentrations, is an essential element for plant and animal life. It is through the intake of the sulphate ion that plants obtain their sulphur requirement. Sulphate is second only to the carbonate ion (CO_3^-) (see alkalinity) in abundance in surface waters. It originates from sedimentary rocks such as shale, as well as from industrial effluents and mine drainage wastes. The use of blue-stone (copper sulphate) for algae control can also lead to increased levels of sulphate in water. Excessive sulphate levels can have a laxative effect on consumers.

Sulphate	**Water Use Category**				
(mg/L)	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	500 (H)	1000			

(H) = Guideline based on health considerations.

Total Dissolved Solids (mg/L)

Total dissolved solids are a measure of the filterable salts and minerals in a water sample. High total dissolved solids concentrations usually result in poor taste and may, if high enough and depending on the composition, become a health concern. Total dissolved solids may consist of a single dominant solute (salt or mineral) or a large number of different solutes salts depending on the water source.

Total Dissolved Solids	**Water Use Category**				
(mg/L)	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	500 (A)	3000			
Objective				700 – 1000*	

(A) = Guideline based on aesthetic considerations.

* = Objective of 700 mg/L for periods when greenhouse irrigation likely to occur, while 1000 mg/L for periods when field, park, and garden irrigation is likely to occur.

Total Suspended Solids (mg/L)

Total suspended solids is the non-filterable residue in a water sample. As the name implies, it refers to suspended rather than dissolved particles, and includes clay, silt, large inorganic and organic molecules, and even small aquatic plants and animals. Land run-off and algal blooms are major contributors to the level of total suspended solids in surface waters. High levels of total suspended solids in a water body result in a lower degree of light penetration. This may be advantageous in that it leads to a decline in algae and weed growth. However, it can lead to problems with water intake filters, decrease the success of chlorination, and reduce suitability for desirable aquatic organisms. There are no guidelines for total suspended solids surface water supplies and objectives for protection of aquatic life vary based upon ambient background conditions.

Suspended Solids (total)	**Water Use Category**				
(mg/L)	Domestic	Livestock	Aquatic Life *	Irrigation	Recreation
Objective (background ≤ 25 mg/L)			Max increase of 5 mg/L		
Objective (background ≤ 250 mg/L)			Max increase of 25 mg/L		
Objective (background > 250 mg/L)			Max increase of 10 %		

* = Objective value varies with background values.

Turbidity (NTU)

Turbidity is a measure of light penetration through the water column. As such, it is directly related to total suspended solids, and is often used to indicate overall water clarity. Water turbidity is an important consideration in the design of drinking water treatment systems since the success of disinfecting by chlorination is related to the amount of suspended solids in the water. In the case of high turbidity values, water treatment systems have to be designed to remove suspended particles from the water prior to chlorination, otherwise chlorination is unsuccessful and/or trihalomethanes can be produced.

Turbidity	**Water Use Category**				
(NTU)	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	1.0 (H); 5.0 (A)				
Objective			*		

(A) = Guideline or objective based on aesthetic considerations.
(H) = Guideline or objective based on health considerations.
* = Equivalent induced level of change from site-specific or regional-specific correlation between total suspended sediment and turbidity.

Zinc (mg/L) (Zn^{+2})

Zinc is a heavy metal that is necessary in trace amounts for plant and animal life. In animals it is involved in the activities of digestion enzymes, while in plants it is an important element in chloroplast and hormone production. Zinc is the 24th most abundant element in the earth's crust. It is found mainly in sulphide, carbonate, and silicate minerals. Sulphide minerals containing zinc (*e.g.*, zinc blende (ZnS)) are generally associated with iron, copper, and lead deposits, and zinc production is a by-product of mining for these elements. Zinc is used as a

protective coating for iron and steel and as a component in numerous metal alloys such as brass (with copper) and bronze (with copper and tin). Zinc enters the aquatic environment through weathering of minerals and rocks, and through mining waste, sewage, and landfills. In water it exists in many suspended and dissolved forms, from simple ions (Zn^{+2}) through to complexes in which it is bound to clay and organic particles and colloids. Overall concentrations of zinc in water tend to be relatively low, and in non-polluted surface waters rarely exceed 0.10 mg/L in Canada. Some zinc does find its way into drinking water because of the use of zinc in plumbing materials. The major source of zinc in the human diet is through food. Ingestion of zinc higher than the recommended daily requirement of 4 to 10 mg has no adverse affect on health. However, excessive concentrations of zinc in drinking water can cause taste problems.

Zinc	**Water Use Category**				
(mg/L)	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	5.0 (A)	50.0		1.0 – 5.0	
Objective			0.036 & 0.166*		

(A) = Guideline based on aesthetic considerations.

* = Objective changes with water hardness ($CaCO_3$ mg/L) concentrations where increasing hardness increases the ability for higher objective values. The listed values are for chronic exposure to dissolved zinc concentrations and for hardness concentrations of 25 and 150 mg/L, respectively.

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Appendix 4. General physical and common water chemistry variables for water quality samples collected from Wanipigow River and Wanipigow Lake during August 2002.

Generic Site Identification	Sample Depth	Sample Date	Water Temperature	pH	Secchi Disk	Conductivity	Total Alkalinity	Bicarbonate Alkalinity	Carbonate Alkalinity	Hydroxyl Alkalinity	Total Solids	Total Dissolved Solids	Suspended Solids	Turbidity	Total Nitrogen	Total Kjeldahl Nitrogen	Ammonia nitrogen	Nitrate Nitrite Nitrogen	Total Phosphorus	Dissolved Phosphorus	Ortho Phosphorus	Particulate Phosphorus
	(m)	(yyyy/mm/dd)	(°C)	(units)	(m)	(uS/cm)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(NTU)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
WR1	0	2002-08-06	21.0	7.05		105	50	61.0	< 0.5	< 0.5		111	8	6.9	0.26	0.25	0.24	< 0.01	0.054	0.021		0.034
WR2	0	2002-08-06	21.0	7.29		100	50	61.0	< 0.5	< 0.5		98	9	7.7	0.21	0.20	0.2	< 0.01	0.059	0.021		0.038
WR3	0	2002-08-06	22.0	7.47		96	44	53.7	< 0.5	< 0.5		106	9	6.7	0.23	0.22	0.22	< 0.01	0.061	0.016		0.045
WR4	0	2002-08-06	21.0	7.38	0.61	91	42	51.2	< 0.5	< 0.5		99	9	7.4	0.03	< 0.02	0.11	< 0.01	0.051	0.017		0.034
WL5	1	1976-05-31	21.5	7.60		65	30	36.6	0.0	0.0	60	60	< 5	2.5	0.71	0.70	0.11	< 0.01	0.030		< 0.02	
WL5	2	1976-05-31		7.30		66	28	34.2	0.0	0.0	64	64	< 5	3.5	0.71	0.70	0.02	< 0.01	0.030		< 0.02	
WL5	1	1977-06-22	21.0	7.60		100	44	52.7	0.0	0.0	80	80	< 5	2.5	0.71	0.70	< 0.02	< 0.01	0.044		0.012	
WL5	2	1977-06-22	20.0	7.60		98	42	51.2	0.0	0.0	80	80	< 5	2.0	0.76	0.75	< 0.02	< 0.01	0.038		0.01	
WL5	0	1980-02-27		6.90		84	36	43.9	0.0	0.0							0.11	0.32	0.062			
WL5	4	1980-02-27		6.90		98	42	51.2	0.0	0.0							0.06	0.18	0.060			
WL5	0	1992-05-19			0.94										0.71	0.70	< 0.02	< 0.01	0.037	0.020		0.017
WL5	0	1992-06-01			0.94										0.65	0.65	< 0.02	< 0.01	0.035	0.016		0.019
WL5	0	1992-06-07			1.07										0.66	0.63	0.038	< 0.01	0.046	0.019		0.027
WL5	0	1992-07-12			0.86										1.00	0.99	< 0.02	< 0.01	0.059	0.040		0.019
WL5	0	1992-07-19			0.86										0.65	0.64	0.02	< 0.01	0.031	0.016		0.015
WL5	0	1992-08-09			1.37										0.76	0.75	0.02	< 0.01	0.029	0.016		0.013
WL5	0	1992-08-15			0.91										0.77	0.76	< 0.02	< 0.01	0.026	0.015		0.011
WL5	0	2002-08-06	21.0	7.34	0.61	90	40	48.8	< 0.5	< 0.5		92	6	7.3	0.21	< 0.2	0.14	< 0.01	0.044	0.017		0.028
WR6	0	2002-08-06	21.0	7.09	0.80	86	40	48.8	< 0.5	< 0.5		98	5	6.1	1.71	1.70	0.14	< 0.01	0.051	0.025		0.026
WR-DS	0	2002-08-07	20.0	7.07		80	34	41.5	< 0.5	< 0.5		91	8	6.2	1.51	1.50	0.13	< 0.01	0.041	0.018		0.022
NNC-VR	0	2002-08-07	17.0	7.03		467	216	264.0	< 0.5	< 0.5		266	3	1.6	0.21	< 0.2	0.06	< 0.01	0.067	0.019		0.048
WR-US	0	2002-08-07	20.0	7.15		64	26	31.7	< 0.5	< 0.5		54	3	2.6	1.91	1.90	0.26	< 0.01	0.029	0.013		0.016

Note: Site WR5 is the same location for historical site identification WQ262 (sample depth at 1 m) and WQ263 (sample depth at 2 m or euphotic zone for that location).
Blanks = no data.

Generic Site Identification	Sample Depth	Sample Date	Calcium Extractable	Magnesium Extractable	Hardness	Manganese Extractable	Iron Extractable	Sodium Extractable	Potassium Extractable	Chloride Soluble	Sulphate Soluble	Total Organic Carbon	Total Inorganic Carbon	Colour TRUE	Dissolved Oxygen	Chlorophyll-a	Biochemical Oxygen Demand	Silica Reactive	Total Coliform	Fecal Coliform	Escherichia coli
	(m)	(yyyy/mm/dd)	(mg/L)	(mg/L)	($CaCO_3$mg/L	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)		(mg/L)	mg/L	(mg/L)	(mg/L)	(no./100 mL)	(no./100 mL)	(no./100 mL)
WR1	0	2002-08-06			58					1.0	1.5			100	7.2	12.2		3.53		10	< 10
WR2	0	2002-08-06			55					0.8	1.4			90	7.2	4.2		3.85		10	10
WR3	0	2002-08-06			52					0.8	1.5			80	8.3	8.3		3.86		60	10
WR4	0	2002-08-06			49					0.9	1.6			80	7.7	4.6		4.36		10	< 10
WL5	1	1976-05-31	5.0	< 5.0	23	< 0.02	0.52	< 10	< 2	< 2	5.0	26.0	5.5	90	7.9	4.6	1.2		4	0	
WL5	2	1976-05-31	7.5	< 5.0	29	< 0.02	0.92	< 10	< 2	< 2	5.0	23.5	6.0	90		6.3			0	0	
WL5	1	1977-06-22	10.0	< 5.0	35	0.02	0.31	< 10	< 2	5.0	10.0	22.5	9.5	60	7.6	6.0	1.3		23	9	
WL5	2	1977-06-22	10.0	< 5.0	35	0.02	0.31	< 10	< 2	4.0	10.0	23.5	9.0	50	7.7	6.7	1.4		9	0	
WL5	0	1980-02-27					0.72					21.0	9.5		10.2						
WL5	4	1980-02-27					1.19					22.5	11.0		6.7						
WL5	0	1992-05-19														4.5					
WL5	0	1992-06-01														1.5					
WL5	0	1992-06-07														3.5					
WL5	0	1992-07-12														10.0					
WL5	0	1992-07-19														2.0					
WL5	0	1992-08-09														7.0					
WL5	0	1992-08-15														10.0					
WL5	0	2002-08-06			49					0.8	1.6			90	7.4	4.4		4.64		< 10	< 10
WR6	0	2002-08-06			47					0.6	1.2			90	6.8	2.1		3.37		50	30
WR-DS	0	2002-08-07			42					0.6	1.3			80	6.7	2.1		2.92		50	100
NNC-VR	0	2002-08-07			219					22.0	0.6			60	1.3	1.7		8.03		80	80
WR-US	0	2002-08-07			33					0.6	1.4			60	7.5	1.9		2.33		100	100

Note: Site WR5 is the same location for historical site identification WQ262 (sample depth at 1 m) and WQ263 (sample depth at 2 m or euphotic zone for that location).
Blanks = no data.

Appendix 5. Total metal water quality data collected from Wanipigow River and Wanipigow Lake during August 2002.

Generic Site Identification	Sample Depth (m)	Sample Date (yyyy/mm/dd)	Total Aluminum (mg/L)	Total Antimony (mg/L)	Total Arsenic (mg/L)	Total Barium (mg/L)	Total Beryllium (mg/L)	Total Bismuth (mg/L)	Total Boron (mg/L)	Total Cadmium (mg/L)	Total Calcium (mg/L)	Total Cesium (mg/L)	Total Chromium (mg/L)	Total Cobalt (mg/L)	Total Copper (mg/L)	Total Iron (mg/L)	Total Lead (mg/L)	Total Lithium (mg/L)	Total Magnesium (mg/L)	Total Manganese (mg/L)
WR1	0	2002-08-06	0.27	< 0.0002	0.0015	0.012	< 0.0002	< 0.0002	0.02	< 0.00004	12.4	< 0.0001	0.0006	< 0.0002	0.0014	0.61	< 0.0002	0.0036	6.53	0.051
WR2	0	2002-08-06	0.34	< 0.0002	0.0016	0.013	< 0.0002	< 0.0002	0.01	< 0.00004	11.9	< 0.0001	0.0013	< 0.0002	0.0020	0.69	< 0.0002	0.0034	6.03	0.049
WR3	0	2002-08-06	0.28	< 0.0002	0.0015	0.011	< 0.0002	< 0.0002	0.01	< 0.00004	11.6	< 0.0001	0.0005	< 0.0002	0.0014	0.58	< 0.0002	0.0032	5.5	0.045
WR4	0	2002-08-06	0.35	< 0.0002	0.001	0.012	< 0.0002	< 0.0002	< 0.01	< 0.00004	11.0	< 0.0001	0.0007	< 0.0002	0.0022	0.62	< 0.0002	0.003	5.22	0.022
WL5	1	1976-05-31																		
WL5	2	1976-05-31																		
WL5	1	1977-06-22																		
WL5	2	1977-06-22																		
WL5	0	1980-02-27																		
WL5	4	1980-02-27																		
WL5	0	1992-05-19																		
WL5	0	1992-06-07																		
WL5	0	1992-07-12																		
WL5	0	1992-07-19																		
WL5	0	1992-08-09																		
WL5	0	1992-08-15																		
WL5	0	2002-08-06	0.36	< 0.0002	0.0009	0.013	< 0.0002	< 0.0002	0.01	< 0.00004	11.0	< 0.0001	0.0006	< 0.0002	0.0015	0.58	< 0.0002	0.0027	5.21	0.015
WR6	0	2002-08-06	0.24	< 0.0002	0.0013	0.011	< 0.0002	< 0.0002	0.01	< 0.00004	11.0	< 0.0001	0.0005	0.0003	0.0013	0.95	< 0.0002	0.0025	4.72	0.118
WR-DS	0	2002-08-07	0.24	< 0.0002	0.001	0.011	< 0.0002	< 0.0002	< 0.01	< 0.00004	9.9	< 0.0001	0.0006	< 0.0002	0.0014	0.85	< 0.0002	0.0023	4.19	0.092
NNC-VR	0	2002-08-07	0.031	< 0.0002	0.0013	0.025	< 0.0002	< 0.0002	0.01	< 0.00004	50.6	< 0.0001	< 0.0002	< 0.0002	0.0009	0.72	< 0.0002	0.0084	22.5	0.167
WR-US	0	2002-08-07	0.12	< 0.0002	0.0008	0.0075	< 0.0002	< 0.0002	< 0.01	< 0.00004	8.1	< 0.0001	0.0004	< 0.0002	0.0011	0.53	< 0.0002	0.0017	3.12	0.052

Note: Site WR5 is the same location for historical site identification WQ262 (sample depth at 1 m) and WQ263 (sample depth at 2 m or euphotic zone for that location).
Blanks = no data.

Generic Site Identification	Sample Depth (m)	Sample Date (yyyy/mm/dd)	Total Molybdenum (mg/L)	Total Nickel (mg/L)	Total Potassium (mg/L)	Total Rubidium (mg/L)	Total Selenium (mg/L)	Total Silicon (mg/L)	Total Silver (mg/L)	Total Sodium (mg/L)	Total Strontium (mg/L)	Total Tellurium (mg/L)	Total Thallium (mg/L)	Total Thorium (mg/L)	Total Tin (mg/L)	Total Titanium (mg/L)	Total Uranium (mg/L)	Total Vanadium (mg/L)	Total Zinc (mg/L)	Total Zironium (mg/L)
WR1	0	2002-08-06	< 0.0001	0.0016	1.02	0.0021	< 0.0002	5	< 0.0002	2	0.03	< 0.0002	< 0.00002	< 0.0001	< 0.0002	0.0093	< 0.0001	0.0012	0.005	< 0.002
WR2	0	2002-08-06	< 0.0001	0.0016	1.03	0.0023	< 0.0002	5.8	< 0.0002	1.7	0.028	< 0.0002	< 0.00002	< 0.0001	< 0.0002	0.0130	< 0.0001	0.0013	0.004	< 0.002
WR3	0	2002-08-06	< 0.0001	0.0012	0.98	0.002	< 0.0002	5.4	< 0.0002	1.6	0.027	< 0.0002	< 0.00002	< 0.0001	< 0.0002	0.0083	< 0.0001	0.0011	0.002	< 0.002
WR4	0	2002-08-06	< 0.0001	0.0013	1.11	0.0023	< 0.0002	6	< 0.0002	1.6	0.026	< 0.0002	< 0.00002	< 0.0001	< 0.0002	0.0110	< 0.0001	0.0012	0.006	< 0.002
WL5	1	1976-05-31																		
WL5	2	1976-05-31																		
WL5	1	1977-06-22																		
WL5	2	1977-06-22																		
WL5	0	1980-02-27																		
WL5	4	1980-02-27																		
WL5	0	1992-05-19																		
WL5	0	1992-06-07																		
WL5	0	1992-07-12																		
WL5	0	1992-07-19																		
WL5	0	1992-08-09																		
WL5	0	1992-08-15																		
WL5	0	2002-08-06	< 0.0001	0.0012	1.01	0.0021	< 0.0002	6.3	< 0.0002	1.6	0.026	< 0.0002	< 0.00002	< 0.0001	< 0.0002	0.0100	< 0.0001	0.0012	0.002	< 0.002
WR6	0	2002-08-06	< 0.0001	0.0011	0.73	0.0017	< 0.0002	4.5	< 0.0002	1.3	0.026	< 0.0002	< 0.00002	< 0.0001	< 0.0002	0.0075	< 0.0001	0.0012	0.052	< 0.002
WR-DS	0	2002-08-07	< 0.0001	0.0011	0.53	0.0015	< 0.0002	4.1	< 0.0002	1.1	0.024	< 0.0002	< 0.00002	< 0.0001	< 0.0002	0.0081	< 0.0001	0.0011	0.004	< 0.002
NNC-VR	0	2002-08-07	< 0.0001	0.0019	1.61	0.0011	< 0.0002	10.9	< 0.0002	25.3	0.095	< 0.0002	< 0.00002	< 0.0001	< 0.0002	0.0019	< 0.0001	< 0.0002	0.003	< 0.002
WR-US	0	2002-08-07	< 0.0001	0.0007	0.44	0.0012	< 0.0002	3.2	< 0.0002	1.1	0.02	< 0.0002	< 0.00002	< 0.0001	< 0.0002	0.0035	< 0.0001	0.0006	0.005	< 0.002

Note: Site WR5 is the same location for historical site identification WQ262 (sample depth at 1 m) and WQ263 (sample depth at 2 m or euphotic zone for that location).
Blanks = no data.

Appendix 6. Dissolved metal water quality data collected from Wanipigow River and Wanipigow Lake during August 2002.

Generic Site Identification	Sample Depth (m)	Sample Date (yyyy/mm/dd)	Dissolved Aluminum (mg/L)	Dissolved Antimony (mg/L)	Dissolved Arsenic (mg/L)	Dissolved Barium (mg/L)	Dissolved Beryllium (mg/L)	Dissolved Bismuth (mg/L)	Dissolved Boron (mg/L)	Dissolved Cesium (mg/L)	Dissolved Cadmium (mg/L)	Dissolved Calcium (mg/L)	Dissolved Chromium (mg/L)	Dissolved Cobalt (mg/L)	Dissolved Copper (mg/L)	Dissolved Iron (mg/L)	Dissolved Lead (mg/L)	Dissolved Lithium (mg/L)	Dissolved Magnesium (mg/L)	Dissolved Manganese (mg/L)
WR1	0	2002-08-06	0.120																	
WR2	0	2002-08-06	< 0.001																	
WR3	0	2002-08-06	0.095																	
WR4	0	2002-08-06	0.140																	
WL5	1	1976-05-31																		
WL5	2	1976-05-31																		
WL5	1	1977-06-22																		
WL5	2	1977-06-22																		
WL5	0	1980-02-27																		
WL5	4	1980-02-27																		
WL5	0	1992-05-19																		
WL5	0	1992-06-07																		
WL5	0	1992-07-12																		
WL5	0	1992-07-19																		
WL5	0	1992-08-09																		
WL5	0	1992-08-15																		
WL5	0	2002-08-06	0.120																	
WR6	0	2002-08-06	0.082																	
WR-DS	0	2002-08-07	0.056	< 0.0002	0.0007	0.0065	< 0.0002	< 0.0002	< 0.01	< 0.0001	< 0.00004	8.5	0.0003	< 0.0002	0.0014	0.44	< 0.0002	0.0018	3.55	0.0170
NNC-VR	0	2002-08-07	0.003	< 0.0002	0.0007	0.018	< 0.0002	< 0.0002	0.01	< 0.0001	< 0.00004	41.7	< 0.0002	< 0.0002	0.0007	0.14	< 0.0002	0.0068	18.80	0.0022
WR-US	0	2002-08-07	0.032	< 0.0002	0.0005	0.005	< 0.0002	< 0.0002	< 0.01	< 0.0001	< 0.00004	7.0	0.0002	< 0.0002	0.001	0.26	< 0.0002	0.0015	2.62	0.0041

Note: Site WR5 is the same location for historical site identification WQ262 (sample depth at 1 m) and WQ263 (sample depth at 2 m or euphotic zone for that location).
Blanks = no data.

Generic Site Identification	Sample Depth (m)	Sample Date (yyyy/mm/dd)	Dissolved Molybdenum (mg/L)	Dissolved Nickel (mg/L)	Dissolved Potassium (mg/L)	Dissolved Rubidium (mg/L)	Dissolved Selenium (mg/L)	Dissolved Silicon (mg/L)	Dissolved Silver (mg/L)	Dissolved Sodium (mg/L)	Dissolved Strontium (mg/L)	Dissolved Tellurium (mg/L)	Dissolved Thallium (mg/L)	Dissolved Thorium (mg/L)	Dissolved Tin (mg/L)	Dissolved Titanium (mg/L)	Dissolved Uranium (mg/L)	Dissolved Vanadium (mg/L)	Dissolved Zinc (mg/L)	Dissolved Zirconium (mg/L)
WR1	0	2002-08-06																		
WR2	0	2002-08-06																		
WR3	0	2002-08-06																		
WR4	0	2002-08-06																		
WL5	1	1976-05-31																		
WL5	2	1976-05-31																		
WL5	1	1977-06-22																		
WL5	2	1977-06-22																		
WL5	0	1980-02-27																		
WL5	4	1980-02-27																		
WL5	0	1992-05-19																		
WL5	0	1992-06-07																		
WL5	0	1992-07-12																		
WL5	0	1992-07-19																		
WL5	0	1992-08-09																		
WL5	0	1992-08-15																		
WL5	0	2002-08-06																		
WR6	0	2002-08-06																		
WR-DS	0	2002-08-07	< 0.0001	0.001	0.39	0.0009	< 0.0002	2.9	< 0.00002	1.0	0.020	< 0.0002	< 0.00002	< 0.0001	< 0.0002	0.0025	< 0.0001	0.0009	0.004	< 0.002
NNC-VR	0	2002-08-07	< 0.0001	0.0018	1.30	0.0011	< 0.0002	8.0	< 0.00002	22.1	0.081	< 0.0002	< 0.00002	< 0.0001	< 0.0002	0.0004	< 0.0001	< 0.0002	0.003	< 0.002
WR-US	0	2002-08-07	< 0.0001	0.0007	0.35	0.0009	< 0.0002	2.3	< 0.00002	1.0	0.017	< 0.0002	< 0.00002	< 0.0001	< 0.0002	0.001	< 0.0001	0.0005	0.005	< 0.002

Note: Site WR5 is the same location for historical site identification WQ262 (sample depth at 1 m) and WQ263 (sample depth at 2 m or euphotic zone for that location).
Blanks = no data.

Appendix 7. General physical and common water chemistry variables for historical water quality samples collected from Wanipigow River and Wanipigow Lake, 1976 - 1992.

Generic Site Identification	Sample Depth	Sample Date	Water Temperature	pH	Secchi Disk	Conductivity	Total Alkalinity	Bicarbonate Alkalinity	Carbonate Alkalinity	Hydroxyl Alkalinity	Total Solids	Total Dissolved Solids	Suspended Solids	Turbidity	Total Nitrogen	Total Kjeldahl Nitrogen	Ammonia nitrogen	Nitrate Nitrite Nitrogen	Total Phosphorus	Dissolved Phosphorus	Ortho Phosphorus	Particulate Phosphorus
	(m)	(yyyy/mm/dd)	(°C)	(units)	(m)	(uS/cm)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(NTU)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
WL7	0	1981-05-31			0.80																	
WL7	0	1981-06-28			0.80																	
WL7	0	1981-07-12			0.75																	
WL7	0	1981-08-03			0.80																	
WL7	0	1981-08-09			0.80																	
WL7	0	1981-08-28			0.80																	
WL7	0	1981-09-07			0.85																	
WL7	0	1982-05-24			0.90																	
WL7	0	1982-06-04			0.75																	
WL7	0	1982-06-13			0.75																	
WL7	0	1982-06-27			0.80																	
WL7	0	1982-07-04			0.70																	
WL7	0	1982-07-18			0.80																	
WL7	0	1982-08-03			0.70																	
WL7	0	1983-05-23			1.00																	
WL7	0	1992-05-19			1.09											0.75	< 0.02	< 0.01	0.031	0.02		0.011
WL7	0	1992-06-01			1.10											0.65	< 0.02	< 0.01	0.022	0.014		0.008
WL7	0	1992-06-07			1.37											0.65	0.038	< 0.01	0.059	0.021		0.038
WL7	0	1992-07-12			0.91											0.73	< 0.02	< 0.01	0.043	0.02		0.023
WL7	0	1992-07-19			0.99											0.64	0.02	< 0.01	0.031	0.015		0.016
WL7	0	1992-08-09			1.19											0.75	0.021	< 0.01	0.034	0.018		0.016
WL7	0	1992-08-15			0.97											0.76	0.021	< 0.01	0.026	0.015		0.011
WL8	1	1976-05-31		7.3		69	30	36.6	0	0	70	70	< 5	3.5		0.6	[illegible]	[illegible]	0.03		< 0.02	
WL8	2	1976-05-31		7.3		71	30	36.6	0	0	54	54	< 5	3.5		0.8	[illegible]	[illegible]	0.03		< 0.02	
WL8	1	1977-06-22	21.5	7.65		101	48	58.6	0	0	72	72	< 5	2		0.7	[illegible]	[illegible]	0.05		0.01	
WL8	2	1977-06-22	22	7.65		101	48	58.6	0	0	88	82	6	2		0.7	[illegible]	[illegible]	0.0445		0.008	
WL8	0	1980-02-27		7.1		97	44	53.7	0	0							[illegible]	[illegible]	0.032			
WL8	2	1980-02-27		6.9		95.2	44	53.7	0	0							[illegible]	[illegible]	0.062			
WL9	1	1976-05-31		7.4		67.6	29	35.4	0	0	50	50	< 5	3		0.7	[illegible]	[illegible]	0.03		< 0.02	
WL9	2	1976-05-31		7.2		65.3	28	34.2	0	0	44	44	< 5	3		0.7	[illegible]	[illegible]	0.03		< 0.02	
WL9	1	1977-06-22	19	7.3		96.4	30	36.6	0	0	88	88	< 5	2		0.7	[illegible]	[illegible]	0.0385		0.0115	
WL9	2	1977-06-22	19	7.3		94.3	40	48.8	0	0	74	74	< 5	2.5		0.75	[illegible]	[illegible]	0.0445		0.0135	
WL9	0	1980-02-27		6.9		96.6	46	56.1	0	0							[illegible]	[illegible]	0.042			
WL9	0	1992-05-19			0.89											0.7	< 0.02	< 0.01	0.031	0.02		0.011
WL9	0	1992-06-01			0.91											0.65	0.02	< 0.01	0.027	0.017		0.01
WL9	0	1992-06-07			0.99											0.7	0.033	< 0.01	0.048	0.02		0.028
WL9	0	1992-07-12			-											0.73	< 0.02	< 0.01	0.05	0.02		0.03
WL9	0	1992-07-19			0.81											0.73	< 0.02	< 0.01	0.033	0.018		0.015
WL9	0	1992-08-09			1.22											0.8	0.021	< 0.01	0.034	0.017		0.017
WL9	0	1992-08-15			0.91											0.76	< 0.02	< 0.01	0.021	0.016		0.005

Blanks = No data.
WL7 = Historial site WQ608.
WL8 = Historical sites WQ264 & WQ265 (both WQ numbers from the same location but represented different depths).
WL9 = Historical sites WQ260 & WQ261 (both WQ numbers from the same location but represented different depths).
Ammonia values = soluble ammonia unless shaded which represents total values.
Nitrate-nitrite values = soluble nitrate-nitrite unless shaded which represents soluble values.

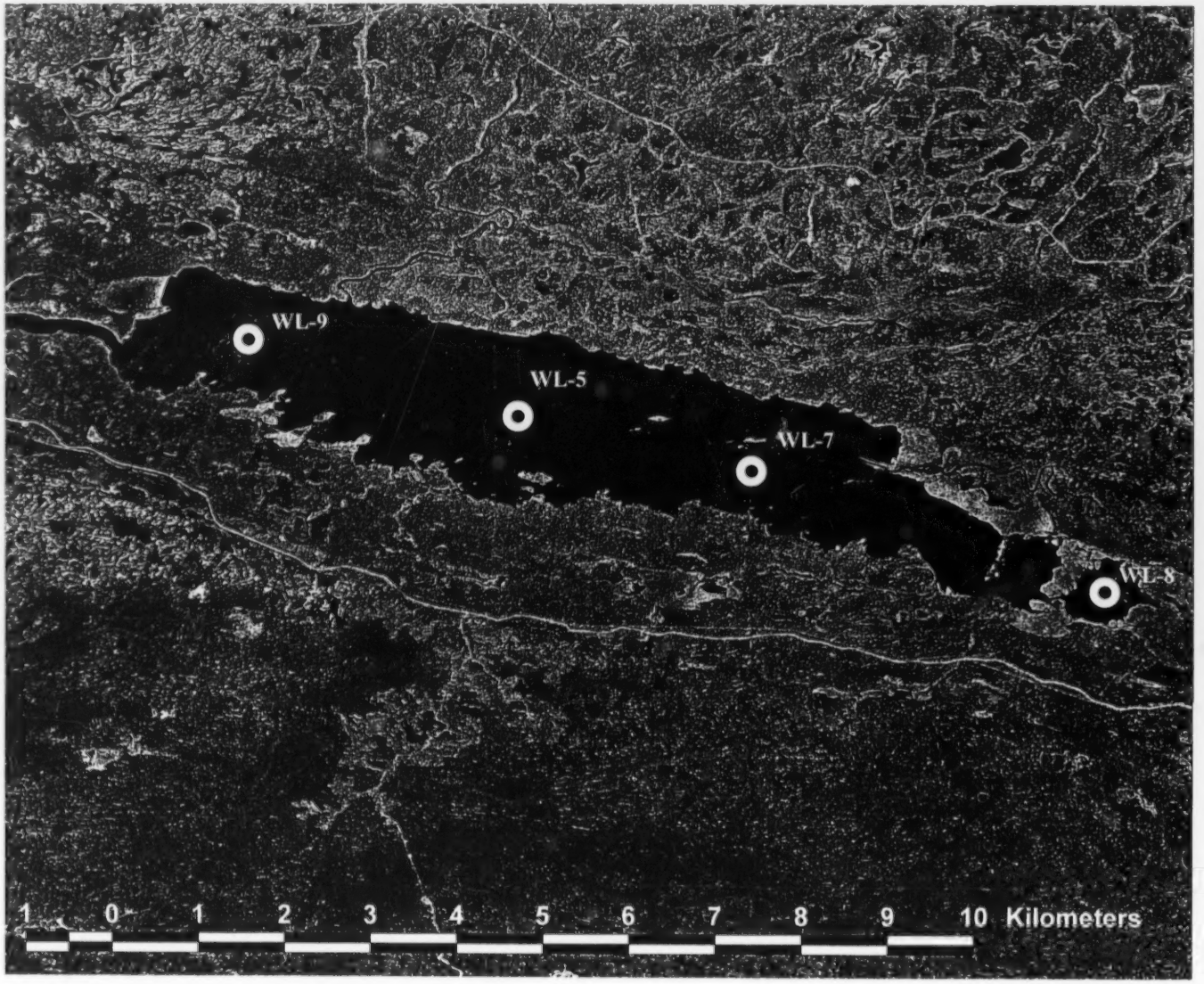
Appendix 7 – General physical and common water chemistry variables for historical water quality samples collected from Wampigow River and Wampigow Lake, 1976 – 1992.

Station ID	Sample Date	Depth	Water Temperature	pH	Conductivity	Total Hardness	Calcium	Magnesium	Dissolved Oxygen	Total Alkalinity	Total Dissolved Solids	Total Suspended Solids	Turbidity	Total Ammonia	Total Kjeldahl Nitrogen	Ammonia Nitrogen	Nitrate Nitrite Nitrogen	Total Phosphorus	Dissolved Phosphorus	Ortho Phosphorus	Particulate Phosphorus
		m	°C		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
WL1	1976/07/21																				
WL1	1977/07/13																				
WL1	1978/07/11																				
WL1	1979/07/17																				
WL1	1980/07/15																				
WL1	1981/07/14																				
WL1	1982/07/13																				
WL1	1983/07/12																				
WL1	1984/07/10																				
WL1	1985/07/09																				
WL1	1986/07/08																				
WL1	1987/07/07																				
WL1	1988/07/05																				
WL1	1989/07/04																				
WL1	1990/07/03																				
WL1	1991/07/02																				
WL1	1992/07/01																				
WL1	1993/06/30																				
WL1	1994/06/29																				
WL1	1995/06/28																				
WL1

Appendix 7 continued. General physical and common water chemistry variables for historical water quality samples collected from Wanipigow River and Wanipigow Lake, 1976 - 1992.

Generic Site Identification	Sample Depth	Sample Date	Calcium Extractable	Magnesium Extractable	Hardness	Manganese Extractable	Iron Extractable	Sodium Extractable	Potassium Extractable	Chloride Soluble	Sulphate Soluble	Total Organic Carbon	Total Inorganic Carbon	Colour TRUE	Dissolved Oxygen	Chlorophyll-a	Biochemical Oxygen Demand	Total Coliform	Fecal Coliform	Escherichia coli
	(m)	(yyyy/mm/dd)	(mg/L)	(mg/L)	($CaCO_3$,mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)		(mg/L)	mg/L)	(mg/L)	(no./100 mL)	(no./100 mL)	(no./100 mL)
WL7	0	1981-05-31														8.6				
WL7	0	1981-06-28														6.0				
WL7	0	1981-07-12														2.5				
WL7	0	1981-08-03														7.8				
WL7	0	1981-08-09														3.6				
WL7	0	1981-08-28														8.9				
WL7	0	1981-09-07														4.4				
WL7	0	1982-05-24														4.6				
WL7	0	1982-06-04														6.0				
WL7	0	1982-06-13														5.2				
WL7	0	1982-06-27														2.4				
WL7	0	1982-07-04														8.3				
WL7	0	1982-07-18														13.2				
WL7	0	1982-08-03														6.5				
WL7	0	1983-05-23														3.9				
WL7	0	1992-05-19														4.5				
WL7	0	1992-06-01														1.0				
WL7	0	1992-06-07														2.8				
WL7	0	1992-07-12														5.5				
WL7	0	1992-07-19														2.5				
WL7	0	1992-08-09														5.0				
WL7	0	1992-08-15														14.0				
WL8	1	1976-05-31														5.0				
WL8	2	1976-05-31	10	< 5	35.3	< 0.02	0.58	< 10	< 2	< 2	5	25	7	90		5.9		0	0	
WL8	1	1977-06-22	10	< 5	35.3	< 0.02	1	< 10	< 2	< 2	5	24	6.5	90		6.7		4	4	
WL8	2	1977-06-22	10	< 5	35.3	0.02	0.28	< 10	< 2	3	10	22	9.5	50	8	5.7	1.7	4	0	
WL8	0	1980-02-27	12.5	< 5	41.3	0.02	0.22	< 10	< 2	3	10	21.5	9.5	50	7.7		1.3	4	0	
WL8	2	1980-02-27					1					27.5	10		11.2					
WL9	1	1976-05-31					1.13					27	11		5.5	4.8				
WL9	2	1976-05-31	7.5	< 5	29.1	< 0.02	0.52	< 10	< 2	< 2	5	22.5	6.5	90		4.5		0	0	
WL9	1	1977-06-22	7.5	< 5	29.1	< 0.02	0.52	< 10	< 2	< 2	5	24	7	100		5.7		4	0	
WL9	2	1977-06-22	10	5	45	0.03	0.41	< 10	< 2	< 2	10	24	9	75	5.9	7.3	5.9	23	0	
WL9	0	1980-02-27	10	< 5	35.3	0.03	0.37	< 10	< 2	5	10	33.5	9	70	6.2		1	23	0	
WL9	0	1992-05-19					0.94					26.5	12			4.5				
WL9	0	1992-06-01														1.0				
WL9	0	1992-06-07														4.2				
WL9	0	1992-07-12														8.5				
WL9	0	1992-07-19														1.0				
WL9	0	1992-08-09														10.0				
WL9	0	1992-08-15														6.5				

Blanks = No data.
WL7 = Historial site WQ608.
WL8 = Historical sites WQ264 & WQ265 (both WQ numbers from the same location but represented different depths).
WL9 = Historical sites WQ260 & WQ261 (both WQ numbers from the same location but represented different depths).
Ammonia values = soluble ammonia unless shaded which represents total values.
Nitrate-nitrite values = soluble nitrate-nitrite unless shaded which represents soluble values.



N
W E
S

Sampling Site Identifications

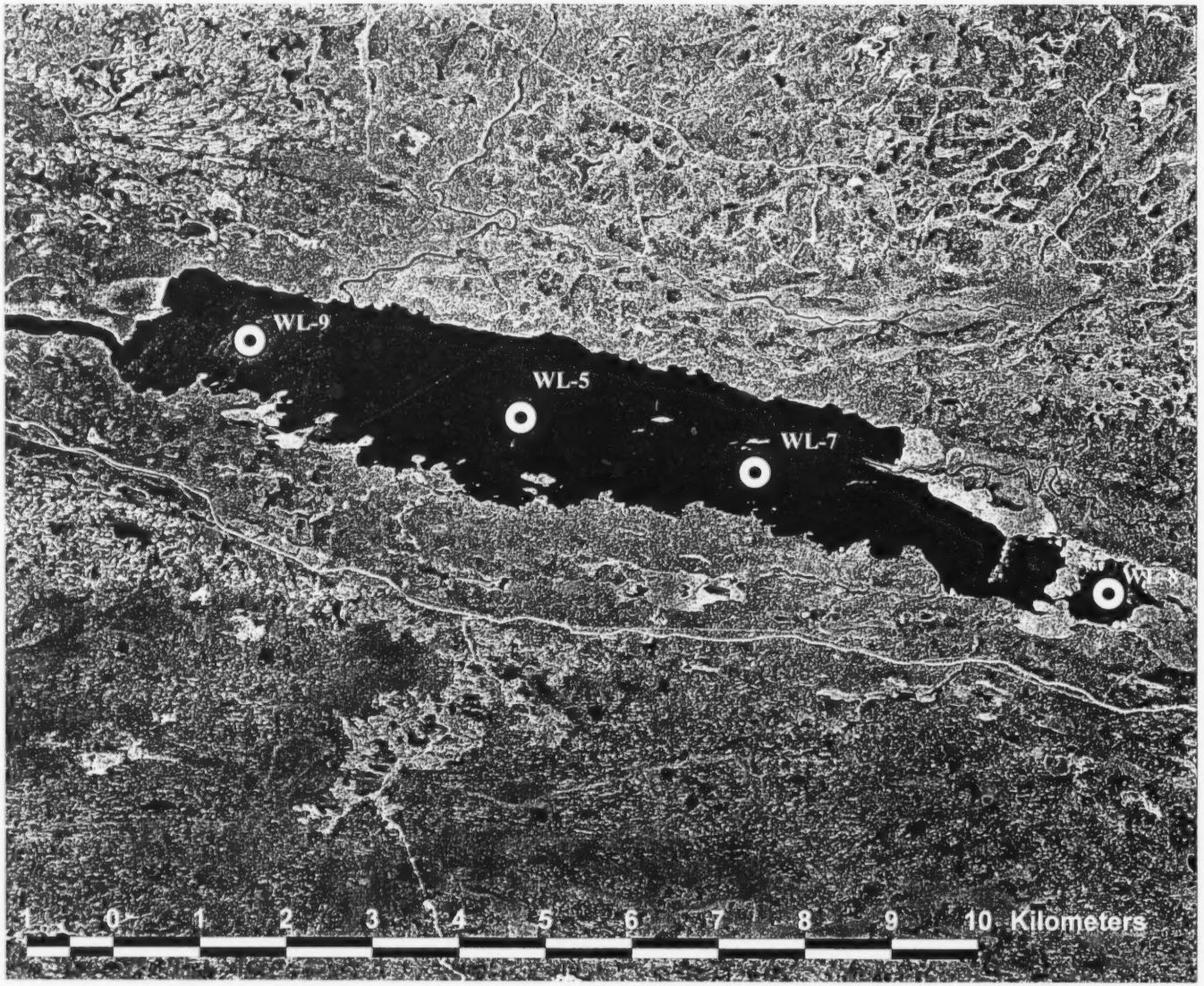
WL-9 = Historical
WQ260 ~ surface samples
WQ261 ~ samples at twice secchi depth
Current Data base
MB05RAS001 = WQ260
MB05RAS002 = WQ261

WL- 5 = Historical
WQ262 ~ surface samples
WQ263 ~ samples at wice secchi depth
Current Data Base
MB05RAS003 = WQ262
MB05RAS004 = WQ263

WL- 7 = Historical
WQ608
Current Data Base
MB05RAS055

WL-8 = Historical
WQ264 ~ surface samples
WQ265 ~ samples at twice secchi depth
Current Data Base
MB05RAS005 = WQ264
MB05RAS006 = WQ265

Appendix 8. Map of Wanipigow Lake showing historical sampling sites and corresponding identification historically and currently used .



N
W E
S

Sampling Site Identifications

WL-9 = Historical
WQ260 ~ surface samples
WQ261 ~ samples at twice secchi depth
Current Data base
MB05RAS001 = WQ260
MB05RAS002 = WQ261

WL- 5 = Historical
WQ262 ~ surface samples
WQ263 ~ samples at wice secchi depth
Current Data Base
MB05RAS003 = WQ262
MB05RAS004 = WQ263

WL- 7 = Historical
WQ608
Current Data Base
MB05RAS055

WL-8 = Historical
WQ264 ~ surface samples
WQ265 ~ samples at twice secchi depth
Current Data Base
MB05RAS005 = WQ264
MB05RAS006 = WQ265

Appendix 8. Map of Wanipigow Lake showing historical sampling sites and corresponding identification historically and currently used .

Appendix 9, Photo 1. Looking downstream at site WR-US on the Wanipigow River, August 2002.

Appendix 9, Photo 2. Looking downstream at site NNC-VR on No-Name Creek (Vanson Road crossing), August 2002.

Arrows denote upstream to down-stream order

Appendix 9, Photo 3. Looking downstream at site WR-DS on the Wanipigow River, August 2002.

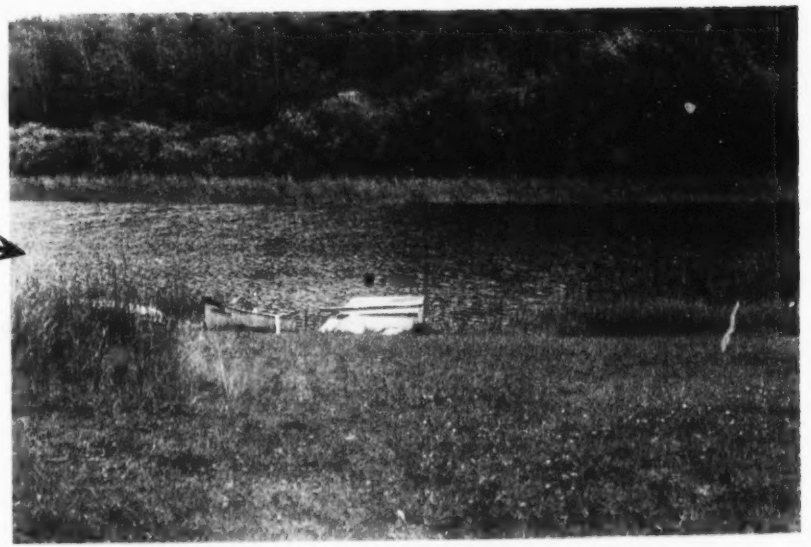
Appendix 9, Photo 4. Looking upstream to site WR-6 on the Wanipigow River inlet to Wanipigow Lake, August 2002.

Arrows denote upstream to downstream order

Appendix 9, Photo 5. Looking toward Wanipigow Lake outlet (near WR-4), August 2002.

Appendix 9, Photo 6. Example of water colouration in Wanipigow River (Currie's Landing boat launch).

Appendix 9, Photo 7. Sampling site WR-3 on the Wanipigow River, August 2002.



Appendix 9, Photo 8. Sampling site WR-2 on Wanipigow River, August 2002.